Comment

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Whilst just over two years have passed since the start of the pandemic and we drift towards a new "normal", the impact of COVID-19 continues to have a long-term effect on science and research.

Although combined effects of national lockdowns and their associated restrictions had a detrimental impact on everyone's research, not everything is as bad as it first appears. The restrictions enforced by the pandemic also acted as a catalyst to drive change. Where once natural inertia impeded the adoption of new technology in science, the way in which we carry out research mutated rapidly as a result of the pressures placed on scientists by the virus and its associated restrictions, leading to a swathe of new approaches to the way we carry out research.

Perhaps the most obvious changes has been in scientific meetings, where previously we spoke to colleagues in person, we now talk mostly on Zoom/MSTeams, which have now arguably become the preferred format despite the slow return to the office.[1] This has perhaps been the greatest immediate change in science, but is also for the better. As meetings moved online, the numbers of international collaborations and diversity of attendees have grown as it appears as though freedom from internal meetings allowed people to explore wider networks that had previously seemed geographically hard.

Lockdown and remote working also stimulated new approaches to teaching, with chemistry kits sent to students by University College London during the first phase of the pandemic illustrating how we can change rapidly when the conditions are right.[2] This sophisticated approach was a result of academics desire to help students and was truly innovative. There were other instances of collective efforts by scientists during the pandemic where they came together to solve Personal Protective Equipment (PPE) shortages in the early days of the pandemic, by 3D-printing face shields and building distributed manufacturing networks, with hospitals working in conjunction with scientists and 3D-printing enthusiasts to supply them with equipment that was in desperate short supply (Fig. 1,A). These drastic changes, involving the rapid set-up and building of collaborative networks has meant that we, as scientists have also realised that we can change if the conditions are right.[3]

In my group, during the first lockdown we set out to learn Arduino programming as a way of keeping in touch and keeping minds focussed on research. Analogous to the example above, Arduino kits were sent to the group via Amazon, enabling them to learn programming whilst they were unable to work in the laboratory, meaning that we were well placed to implement this different research once we returned. This approach was reflected globally with a huge increase in anecdotal reports of scientists learning how to program, typically in Python and due to the restrictions on personnel numbers in laboratories, this also led to changes in industry. Where once external network connections were viewed as an anathema by company IT departments, the need to monitor reactions for safety whilst maintaining a reduced number of personnel in laboratories meant that many companies such as Vernalis could easily implement data logging via low-cost Raspberry Pi boards connected to the network.[4] The advantages of this approach are now obvious in hindsight and these innovations have remained despite the return to a normal workflow. The simple expediency of the need to change, has led to a longer-term cultural shift in the use of new technology.[5]

We also sought to implement this approach in our laboratories, but in a slightly different manner, where we have effectively brought tablet based PCs to the fume hoods so that our in-house Arduino derived software that was developed in lockdown can now connect to low-cost 3D printed continuous flow equipment which then seamlessly reports data to the cloud (Fig. 1,B). This was only made possible by the possibilities of 3D-printing as we were able to adapt older style fume hoods with holders for low-cost tablet PCs. However, because of the sharing nature of the 3D-printing community, these changes can be easily implemented by anyone with access to a 3D printer as the designs are shared for free online in repositories such as Thingiverse.[6] The 3D-printing movement has been a great enabler for research and as the 3D-printing response to covid PPE shortages showed, is able to continue to do so due to the great community spirit shown in the sharing of digital designs.

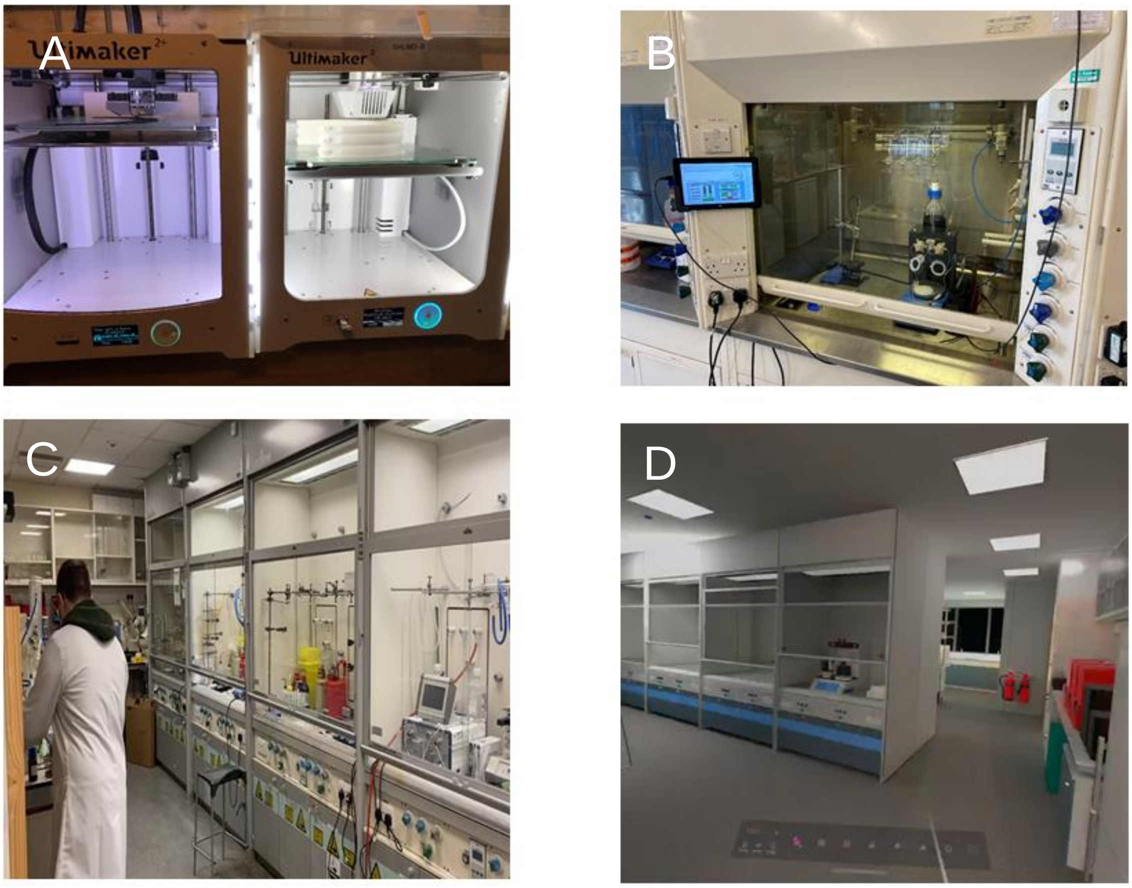

Figure 1: A) 3D printing of PPE. B) Digitisation of fume cupboards. C) Real laboratory. D) Virtual digital twin version of the laboratory.

In another example of digitisation, prior to the pandemic onset, we had started to commercialise our 3D-printed continuous flow system that involving in-person meetings between the UK, US and Germany which stopped abruptly due to lockdown and travel restrictions.[7,8] Whilst we could develop the system slowly via 3D-printing of CAD based designs and Zoom meetings, it was no substitute for in-person discussions. To overcome this, we decided to shift towards using Virtual Reality as a way of meeting, which was perhaps, one of the most paradigm shifting moments of the pandemic for us. Using software from Realworld One and donning headsets, we were able to “meet” in person, bring designs and data into a VR based space and develop a series of prototypes at speeds that previously, even in real life hadn’t been possible.[9] Cognizant of the obvious benefits of VR as a substitute for in-person meetings, we have also more recently developed a digital twin version of my laboratory in VR with associated equipment to facilitate outreach with schools and collaborative working with other scientists. In this manner, children/ collaborators can visit my laboratory by simply putting on a VR headset enabling them to understand the science in a much simpler manner without the need to travel (Fig. 1,C & D). Further developments from this will involve digital input and output from VR into the laboratory to control experimentation, in much the same way as the Chemputer pioneered by Cronin, but simply using controls from within a VR headset.[10] As seen from some of the examples highlighted above, the pandemic has truly disrupted science, but has also allowed technology to accelerate at a much greater pace. These digital adaptation changes forced by Covid are fortunately here to stay.

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