Using the pandemic as a driver for innovation in research

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COVID-19 has resulted in long-term effects on science and research. The way in which we carry out research has had to rapidly adapt as a result of the pressures placed on scientists, leading to the development of innovative approaches to research.

Whilst just over 2 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 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 have been in scientific meetings, where previously we spoke to colleagues in person, we now talk mostly on virtual conferencing platforms, which are now arguably the preferred format despite the slow return to the office[1]. As meetings moved online, the number of international collaborations and diversity of attendees has grown; it appears as though freedom from internal meetings has allowed people to explore wider networks that were previously geographically limited.

Lockdown and remote working also stimulated new approaches to teaching. University College London sent chemistry kits to students during the first phase of the pandemic so they could complete practical lessons from home[2]. This sophisticated approach was a result of the desire of academics to help students and illustrates how we can adapt when the conditions are right. Another instance of collective efforts by scientists during the pandemic was to solve personal protective equipment (PPE) shortages by 3D printing face shields and building distributed manufacturing networks. Hospitals worked in conjunction with scientists and 3D-printing enthusiasts to supply them with equipment that was in desperate short supply (FIG. 1a). These drastic changes, involving the rapid set-up and building of collaborative networks, have meant that we, as scientists, have also realized that we can change if the conditions are right[3].

During the first lockdown, my research group set out to learn Arduino programming as a way of keeping in touch and keeping minds focused on research. This enabled my group to learn programming whilst they were unable to work in the laboratory, meaning that we were well placed to implement this new-learned 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 owing 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 sought to implement this approach in our laboratories, but in a slightly different manner. We have connected our in-house Arduino-derived software, developed during lockdown, to low-cost 3D-printed continuous flow equipment that can seamlessly report data to the cloud (FIG. 1b). This was only made possible by the potentials of 3D printing, as we were able to adapt older-style fume hoods with holders for low-cost tablet PCs. Owing to 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 available in repositories such as Thingiverse. The 3D-printing movement has been a great enabler for research and, as the 3D-printing response to PPE shortages showed, is able to continue to do so owing to the great community spirit shown in the sharing of digital designs.

Before the pandemic, we had started to commercialize our 3D-printed continuous IKA FLOW system; this involved in-person meetings between the UK, USA and

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Fig. 1 | **Examples of innovation during the pandemic. a** | 3D printing of personal protective equipment. **b** | Digitization of fume cupboards. **c** | Real laboratory. **d** | Virtual digital twin version of the laboratory.

Germany that stopped abruptly owing to lockdown and travel restrictions[6]. Whilst we could develop the system slowly via 3D printing of CAD-based designs and virtual meetings, it was no substitute for in-person discussions. To overcome this, we decided to shift towards using virtual reality (VR) as a way of meeting, which was perhaps one of the most paradigm-shifting moments of the pandemic for our group. Using software from Realworld One and donning headsets, we were able to meet, bringing designs and data into a VR-based space to develop a series of prototypes at speeds that previously even in real life had not been possible. Cognizant of the obvious benefits of VR as a substitute for in-person meetings, we have 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 or 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. 1c,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[7].

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-19 are fortunately here to stay.

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Competing interests
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