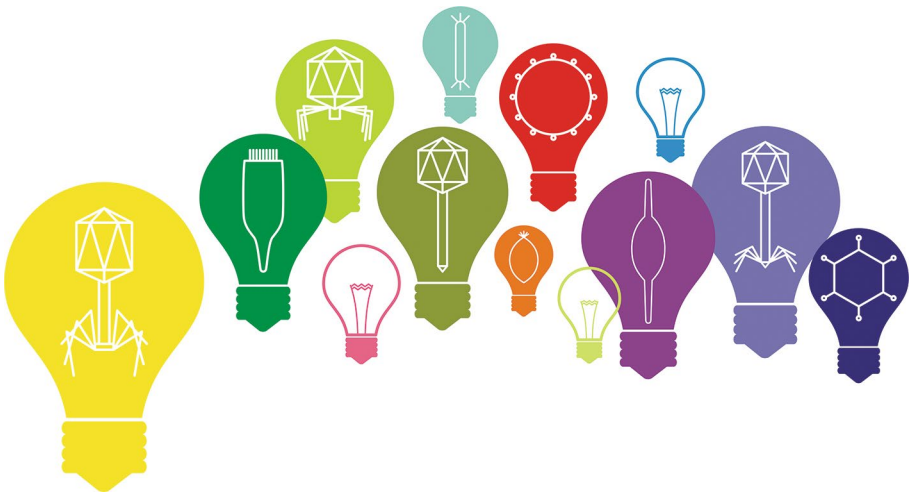
Innovative teaching in the digital age goes viral

Innovations in teaching STEM subjects can help build critical science literacy and address global economic needs. Virology teachers and researchers are actively developing and integrating innovative educational materials for students, creating engaging teaching programs and improving information platforms for the general public.

Esperanza Gomez-Lucia, Christopher H. Logue, Marek S. Szyndel and Rob Lavigne

Viruses affect many aspects of our daily lives, in human and veterinary medicine as well as the plant and animal agricultural industries. As such, it is a responsibility of virologists to disseminate evidence-based virology knowledge through educational channels and to the general public[1]. Yet, in both activities, educators are facing critical challenges. In higher education, recruiting students for STEM (science, technology, engineering and mathematics)-focussed studies, and finding available resources to support high quality and accessible education, can be problematic, particularly in low- to middle-income countries[2]. Teachers often operate in an environment that demands innovative teaching, yet provides only a limited budget to do so. Public access to reliable scientific knowledge can face even greater challenges. The landscape of journalism is changing, occasionally with emphasis placed on the provision of bite-sized nuggets of information to attract audiences on social media, rather than due diligence on fact checking. Unfortunately, active dissemination of disinformation has become commonplace, driven by commercial or specific ideological interests[3]. An example of this in the field of virology is the false reporting of damaging consequences of vaccination, associated with scientifically unfounded, yet widespread, deliberate misinformation and misrepresentation of facts[4]. These elements lead to an increasing gap in knowledge and trust between scientists and the general public — between fact and fiction — and necessitating improved communication and dissemination of information from objective, factual sources.

Several virologists have established initiatives to bridge this gap and provide factual information, through creative and integrated teaching programs. Numerous blogs and online resources within the virology field offer information in an engaging manner. One instance is the popular 'This Week in Virology' (TWiV) podcast, produced by the independent podcast network MicrobeTV, which has been running since 2008 and is hosted by Vincent Racaniello and Dickson Despommier, of Columbia University, New York[5]. This enjoyable and entertaining podcast provides an excellent stage for scientists to discuss the latest developments in the various fields of virology, while simultaneously educating listeners on a specific topic and providing further fact-checked resources for independent learning. Racaniello also hosts several of these podcasts live to packed rooms at scientific conferences throughout the year. Crucially, TWiV combines evidence-based virology in an engaging and accessible format for the academic and layperson alike. The renewed popularity of comic books has also provided a novel platform for information dissemination, such as the Cimaza virology comics developed by Susan Nasif and collaborators. These award-winning comics address debunking vaccine myths through a fact-filled and engaging narrative designed to appeal to adults and teenagers (http://www.cimazacomics.com/). To date, several thousand copies have been sold on copyright and are displayed in waiting rooms and classrooms. The website itself receives a close to 7,000 visitors annually. Other teaching innovations in this field include the creation of several Massive Open Online Courses (MOOCs) in the virology field (https://www.mooc-list.com/tags/virology). Racaniello again leads the way through his freely available online undergraduate virology course at Columbia University (now also translated into Spanish; http://www.virology.ws/course/). The Complutense University of Madrid and l'École Nationale Vétérinaire d'Alfort have produced an engaging veterinary virology MOOC 'Animal Viruses: their transmission and the diseases they produce', aimed at undergraduates, professionals and the general public (also available in English and Spanish; https://www.futurelearn.com/courses/animal-viruses/). Though relatively expensive in production, MOOCs are attractive because they bring the science, in this case virology, from well respected academic providers to learners from all over the world — providing an interactive platform that, for many, is the only opportunity to follow specialized courses. For example, in its second run in April 2018, 'Animal Viruses' had 1,800 joiners from 117 countries, including Sudan, Algeria, Indonesia, Vietnam, Nepal and Sri Lanka, among others.



Illuminating virology. Illustration by Mikolaj Wlodarczyk.

When it comes to accessing hands-on laboratory training, several training courses are available for learners to attend in person, including the 'Novel and Dangerous Pathogens (NADP) Training' courses at Public Health England, Porton Down, in the UK (https://www.phe-protectionservices.org.uk/nadp/courses/list). These courses predominantly support accredited, hands-on training in high-containment laboratories and in field-certification of microbiological safety cabinets; however, they also provide several courses involving interactive distance eLearning modules, such as working safely in Class I and III microbiological safety cabinets (http://www.ehealthlearning.org.uk). Also in the NADP Training pipeline is the move to incorporate point of view video and virtual/ augmented reality (VR/AR) training resources as an option for remote laboratory training where access to a physical laboratory is not available. The availability of affordable VR headsets, and, more recently, wireless gloves (shortlisted in Time Magazine's '50 Best inventions of 2018')[6], will allow for a truly immersive format of remote, virtual, hands-on laboratory training in the future, in areas where access to laboratories is limited. Students would only require a smartphone and VR headset to be taught basic laboratory techniques, before ever entering a laboratory. Other hands-on laboratory training includes SEA-PHAGES (Science Education Alliance-Phage Hunters Advancing Genomics and Evolutionary Science), experimental courses offered in the United States and covering microbiology, molecular biology and medical laboratory, aimed at the discovery of bacterial viruses and their analysis[7].

A new teaching resource for virologists, virology educators and researchers is the Innovirology website (www.innovirology.com), which brings together educational experts and virologists to develop and share various training resources for educators of high-school, undergraduate and post-graduate students, and to support the distribution of accurate virology knowledge to the general public. The community includes over 350 registered higher education teachers from more than 30 countries, sharing syllabi, protocols, webinars and virology laboratory protocols that are developed into an online 'e-Manual'. The website is home to interactive online courses in a Storyline eLearning format, as well as computer and smartphone games such as 'Virtual Epidemic' (http://epidemia.sevirologia.es/). Furthermore an e-book entitled *Virology: An Interactive Guide*, provides an overview of the field in a highly interactive manner using e-learning modules, and is free for anyone to use[8]. In the last year, the web-based material has been accessed by more than 6,000 visitors in over 120 countries.

The e-book has also been adopted by universities in low- to middle-income countries (for example, Universidad San Francisco de Quito (USFQ), in Ecuador) as an online course resource for existing postgraduate courses in virology. Additionally, the incorporation of Twitter, Dropbox, WeTransfer and, most effectively, WhatsApp groups as a means of information dissemination and sharing, has been successfully tried and tested at USFQ. This provides a level of personal ownership in the student discussions outside of lecture theatres and labs, while also allowing for lectures, URLs, additional reading material and assignments to be sent directly to the student's tablet or smartphone, meaning students can access the next day's lectures at any time after class.

The existence of teaching innovations relies on engagement by their creators and individual initiative, as well as sustained financial support, yet their impact is often difficult to quantify. The SEA-PHAGE course has been taken by over 4,800 students at 73 institutions in just five years, and was preceded by its inception at the University of Pittsburgh[9]. The SEA-PHAGES program can be viewed as a single intervention within a large educational context, and the aim is to inspire and engage all students, allowing them to enter their chosen profession with an enlightened view of science, how science is done and who does it (G. Hatfull, personal communication).

All of the initiatives described herein are not intended to replace more traditional learning methods for high-school and undergraduate students. But, when well-integrated, they can make those courses more motivational and approach the learning of science in general, and virology in particular, with resources more approachable for teenagers and young adults. This too includes the restructuring of subject fundamentals in an engaging and accessible way for the next generation of virologists, as physical libraries are gradually transferred into the hands of students through tablets and smartphones. We are confident that this will improve general knowledge of virology in a sustainable manner (as interactive e-learning replaces text-based workbooks) and will excite minds towards further education or employment in this field.

Sustaining the maintenance and development of such initiatives remains a challenge, since they are often dependent on temporary support programs and finite funding schemes. For example, the Innovirology programme received its funding from the European Union through Erasmus+ in 2014, with a maximum of 36 months. The move from textbook to online platforms may bring opportunities for funding through sponsorship and advertising, although its scientific integrity should not be compromised by third-party commercial interests. Licensing may be another model of sustainability, but that too is fraught with inequalities depending on the socioeconomic location of the learner. Lastly, some universities also modestly fund projects for innovative teaching. An example of this is the Complutense University of Madrid and the University of Navarra, who both support the blog microBIO (https://microbioun.blogspot.com/). Another option would be to place greater emphasis towards generating outputs for dissemination of scientific data, and their integration into student curriculums, in research grant submissions. Educators could be encouraged develop teaching curricula to best utilize the technologies of the time and, through strengthening interactions with journalists and field leaders, help to actively identify misinformation and offer a source of unbiased, trustworthy material.

Viruses affect us all, and increasing our knowledge in how to tackle and further understand them is interlinked with both the format that knowledge embodies and the reliability of the information. The move to bring physical laboratory training into virtual and augmented reality will, hopefully, assist in providing technical virology and biosafety training to even the most remote areas.

A non-biased, fact-based repository for teaching resources, such as Innovirology, combined with interactive podcasts, such as TWiV, allow scientists and non-scientists alike to participate in fact-based discussions and offer the best opportunity to keep science open, engaging, fact-based, reliable and interesting, in the digital and virtual age. ❐

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All authors are members of the Innovirology Consortium. For general information about the Innovirology program, please contact E.G.-L. For questions related to access to Innovirology online resources, please contact C.H.L. For general questions and comments related to this Comment, please contact R.L.

Competing interests

The authors declare no competing interests.