DOI: 10.1002/anie.201304861

Conveying the Excitement of Chemistry on YouTube

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How do you do best communicate the excitement of chemistry with young people, the next generation of chemists and engineers? This is a question faced by many chemists who have enjoyed years of professional success, but for whom outreach has always been a slightly nebulous term. A good starting point is to ask what made *you* become a chemist?

When we asked researchers at the University of Nottingham what triggered their interest in chemistry, the reasons were fascinating. "I wasn't good enough at maths to become a physicist", "A girl I liked was taking chemistry", and "I had an inspiring chemistry teacher". In fact, many chemists were first inspired by a teacher. The problem is that teachers often struggle to be inspiring. So how can an enthusiastic chemist assist teachers to inspire the next generation of chemists?

The aim of this Editorial is to help to start answering this question. We will do this by describing how a group of chemists at Nottingham has serendipitously found one way of communicating, namely by collaborating with filmmaker Brady Haran (co-author of this Editorial) to make chemistry videos for YouTube. The group includes Neil Barnes, Jim Gamble, Debbie Kays, Andrei Khlobystov, Pete Licence, Steve Liddle, John Moses, Rob Stockman, Samantha Tang, Darren Walsh, and Martyn Poliakoff. Our project, the Periodic Table of Videos (PTOV), has been successful on several levels and the outcome has been quite different from our initial expectations.

The PTOV began with the simple idea of making a short video about each of the 118 elements in the periodic table. We had some doubts as to what could be said about the superheavy elements, where only a few atoms have ever been synthesized, but these worries were ignored in the initial excitement of filming. We began in June 2008, and in only five weeks we had finished 120 films (one for each element, plus an introduction and a "trailer"). The videos are hosted on YouTube and can be viewed via a dedicated website www.periodicvideos.com or the YouTube channel page http://www.youtube.com/periodicvideos.

Given the speed of production, we did not expect too much impact; perhaps some interest from young people and hardened YouTube addicts? To our surprise, the project really caught the public imagination and attracted considerable press coverage. Our viewers' enthusiasm persuaded us to continue, and we have now been making chemical videos for almost five years. By the end of the second week of May 2013, PTOV had 478 videos, more than 41 million views and more than 250000 YouTube subscribers who receive alerts each time a new video is uploaded. The videos now extend well beyond the elements themselves, and include molecules, reactions, chemistry-related news (e.g., the red sludge in Hungary and the Fukushima disaster in Japan), and road trips exploiting the opportunities presented by our team's overseas travel (e.g., to Brazil, Ethiopia, India, and Australia). Although the scope of PTOV has expanded well beyond the elements, we continue to use the original name because it has become an established "brand".

Many universities are starting to broadcast free lecture courses, so-called massive open on-line courses (MOOCs), which are attracting huge numbers of students across the world. PTOV is not a MOOC. It is quite different. It does not provide lectures and, indeed, breaks many conventions of educational film-making. There are no scripts, no predefined educational outcomes, and no particular target audience. Most unusually for academics, the subjects have also ceded editorial control entirely to the filmmaker. The first time that any of the chemists see the videos is after they have been uploaded on YouTube. All of this means that our videos "feel" different from most educational material from universities and the viewers respond very positively.

YouTube provides instant feedback. Our occasional mistakes are often spotted faster than by the students in our face-to-face university lectures. We quickly and brutally learn what material our viewers find most interesting. The results are unexpected; a video entitled "Can you drink heavy water?" has attracted slightly more views than one showing the explosive reactions of elemental fluorine. In principle, we could use viewers' feedback to improve future videos but, in practice, most of our viewers seem to consider almost any chemistry-related video to be interesting!

Given the number of viewers, we cannot identify most of them individually, although we know that they are

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located in almost every country in the world. The adult audience extends far beyond professional chemists or educators, ranging from European royalty to ordinary workers. One told us: "I never took chemistry in school but I have enormously enjoyed these videos. I work in a high school in the US, I am a janitor. I will give your website to the science department. I am sure that it will be used in their classes". And there are many children too; for example from Australia: "My name is George. I am 8 and like chemistry very much" or from Jakub, aged 13, in the Czech Republic: "Even my two year old brother likes your video about concrete". Our position is reminiscent of small, highly specialized internet companies that are now flourishing. The internet allows us to reach inquiring minds wherever they are located in the world, in a way that would have been quite impossible even a few years ago.

The real surprise for us, the chemists, has been how we can interact with our audiences on two levels. Firstly, we reach huge audiences; on occasions, more than 200 000 people have watched a particular video in just a few days. This is far more than the total number of people that any one of us has addressed in all of our conventional lectures put together. Secondly, individual viewers feel that we are talking to them personally and come to consider us to be friends. Sometimes they ask questions which are sufficiently general that they warrant answering with a video, such as the question that we mentioned at the start of this Editorial about why we became chemists. At other times, viewers consult us on specific problems. These can be alarming but straightforward: "Just a quick question, My dad ordered in some 70% HNO_3, 96% H_2SO_4, and 36% HCl, could you give me some advice on how to store and protect ourselfes (sic) from injury whilst using the acids?". Occasionally, they are more challenging, such as this message from Serbia: "We have written a second paper entitled 'Mathematical modeling of the effect of temperature on the rate of a chemical reaction' … my teacher is currently keen on having the paper published in an international journal, and, being familiar with your YouTube channel and your profession, she suggested me asking you whether you could help".

This message brings us back to the question of teachers. Many of the e-mails and letters that we receive show that teachers are using our videos in the classroom; for example, a recent e-mail from the UK: "We watch your videos, for what seems like every chemistry lesson as our teacher is obsessed with you …" It's clear from the messages that teachers enjoy our enthusiastic approach and our demonstrations of reactions that cannot be carried out safely in schools. Also, our videos go to normally inaccessible places, for example, to see the gold in the vaults of the Bank of England, or plutonium chemistry at the National Nuclear Laboratory. Sometimes teachers have journeyed to Nottingham just to thank us, even bringing small presents from their pupils.

Taking things further, in 2013, we will launch a whole periodic table of annotated videos on the TED website http://ed.ted.com, where each video will have a set of graded questions for pupils to answer. The advantage of this approach is that individual teachers will be able to "flip" the videos and modify the questions to be more suited to the needs of their particular classes.

Has the success of PTOV been just luck? Perhaps not, because Haran has applied the same approach with completely different casts of scientists to create several other equally successful YouTube channels covering physics http://www.sixtysymbols.com, maths http://www.numberphile.com, astronomy http://www.deepskyvideos.com, and more.

The lessons from our project are perhaps quite general. First, science communication can be a rewarding activity for chemists. It is not for everyone but, if you are interested, you should not be discouraged because you lack previous experience. None of the chemists in our team had made videos before the start of PTOV, but all of them have felt positive towards the project. Secondly, participating in outreach does not have to be time-consuming. Each of the academics in our project has continued to be research-active and to publish in high-impact journals. This success has been achieved by collaboration with a professional filmmaker who understands the medium. In effect the filmmaker is a conduit, helping the chemists to convey the excitement that they feel about chemistry without being unduly technical or boring.

We live in exciting times for the development of both chemistry and social media. The challenge is how to couple the excitement in the two fields. As in other areas of chemical activity, we believe that the answer is not to copy what has been done before but to harness the rapid rise of the next social medium (such as Twitter or similar) to convey our collective passion for chemistry to new generations. So we give you every encouragement to try. Do something different!

Finally, let's return to one of our viewers' questions. We were asked: "If you had not become a chemist, what would you have liked to do?" Our team's answers included being a rock star, owning a music shop, and making TV advertisements. What would you have done? Could science communication be a way to unlock your hidden ambition?