to faculty, postdoctoral fellows, and other researchers.

Researchers should also consider collaborations with specialists, such as artists, animators, and designers, to create more effective visualizations. A prominent historical example is the long-term collaboration between artist Irving Geis and crystallographer Richard Dickerson. Geis was an illustrator with *Scientific American* when he was asked to create a detailed painting of a 3D model of myoglobin, the first protein to have its structure solved by X-ray crystallography, in 1958 [12,13]. Geis went on to work with Dickerson to create iconic paintings and drawings of numerous molecules that have graced the pages of textbooks and journals.

Conferences that bring together experts in different fields can seed new collaborations and provide a venue for insightful discussions. Meetings of particular interest for biological visualization and communication include VizBi[ii], the Gordon Research Conference on Visualization in Science and Education[iii], the IEEE Scientific Visualization (SciViz) Conference[iv], and the annual meeting of the Association of Medical Illustrators (AMI)[v].

Visualization is a vital component of modern scientific research, allowing us to both better understand the processes we study and engage broad audiences. Our community has much to gain by encouraging scientists to create more and better visual models, whether by pencil, stylus, or mouse, and to share them openly with one another and with the public.

Resources

[i] https://blog.twitter.com/2014/what-fuels-a-tweets-engagement

[ii] http://vizbi.org/

[iii] www.grc.org/programs.aspx?id=14029

[iv] http://ieeevis.org/

[v] http://ami.org/annual-meeting

[1]Department of Biochemistry, University of Utah, Salt Lake City, UT 84112-5650, USA

*Correspondence: jiwasa@biochem.utah.edu (J.H. Iwasa).

http://dx.doi.org/10.1016/j.it.2016.02.002

References

1. Harris, J.C. (2010) Galileo Galilei: scientist and artist. *Arch. Gen. Psychiatry* 67, 770–771
2. Iwasa, J.H. (2010) Animating the model figure. *Trends Cell Biol.* 20, 699–704
3. Barber, M.E. and Elde, N.C. (2014) Nutritional immunity. Escape from bacterial piracy through rapid evolution of transferrin. *Science* 346, 1362–1366
4. Newe, A. *et al.* (2014) Application and evaluation of interactive 3D PDF for presenting and sharing planning results for liver surgery in clinical routine. *PLoS ONE* 9, e115697
5. Bress, N.E. *et al.* (2009) Snapshot: convenient, comprehensive, and now clickable. *Cell* 138, 1034
6. McGlll, G. (2008) Molecular movies. . . coming to a lecture near you. *Cell* 133, 1127–1132
7. Johnson, G.T. and Hertig, S. (2014) A guide to the visual analysis and communication of biomolecular structural data. *Nat. Rev. Mol. Cell Biol.* 15, 690–698
8. Iwasa, J.H. (2015) Bringing macromolecular machinery to life using 3D animation. *Curr. Opin. Struct. Biol.* 31, 84–88
9. Wong, B. (2010) Points of view: color coding. *Nat. Methods* 7, 573
10. Krzywinski, M. and Savig, E. (2013) Points of view: multidimensional data. *Nat. Methods* 19, 595
11. O'Donoguhue, S.I. *et al.* (2010) Visualizing biological data: supplement issue. *Nat. Methods* 7, S1–S68
12. Kendrew, J.C. *et al.* (1958) A three-dimensional model of the myoglobin structure obtained by X-ray analysis. *Nature* 181, 662–666
13. Kendrew, J.C. (1961) The three-dimensional structure of a protein molecule. *Sci. Am.* 205, 96–110

Special Issue: Communicating Science

Scientific Life

The Whiteboard Revolution: Illuminating Science Communication in the Digital Age

Florie Anne Mar,[1,*,@] Jose Ordovas-Montanes,[2] Nir Oksenberg,[3] and Alexander M. Olson[1]

Journal-based science communication is not accessible or comprehensible to a general public curious about science and eager for the next wave of scientific innovation. We propose an alternative medium for scientists to communicate their work to the general public in an engaging and digestible way through the use of whiteboard videos. We describe the process of producing science whiteboard videos and the benefits and challenges therein.

A Gap in Science Communication

What is the best way for scientists to communicate their knowledge and expertise? For dissemination among scientists, the paper-in-journal model has existed in some form since 1665 [1]. More recently, the internet era has given publishers the opportunity to evolve this process, including animated graphics or videos to enhance articles [2]. Despite this generally more accessible style, it still reaches only a very specific audience: a scientist's peers (and perhaps overly enthusiastic family members). Because of the difficulties of digesting journal articles, the large majority of citizens often rely on journalist-generated and media-curated content to enrich their understanding of our biological, chemical, and physical world. There is a significant gap in science communication between the research paper and the newspaper article, and we believe that scientists are the best equipped to bridge this gap.

Given that most research worldwide is supported by public funds, scientists should view the communication of results to the public, in a digestible manner, as an essential component of their research program. The American Association for the Advancement of Science (AAAS) has been very vocal about this issue and has conducted surveys to assess public support for science in the USA [3]. The results revealed a stark contrast between how scientists and the public viewed certain major scientific advances such as genetically modified (GM) food, animal research, evolution, vaccines, and climate

change. These gaps in scientific understanding and acceptance can lead to important policy outcomes, including the labeling of GM foods, funding for stem cell research, and CO_2 emission regulations. Reliable communication of the achievements and failures inherent to the scientific process is one way to ensure evidence-based decision making by improving transparency, enhancing public trust in science, and closing these gaps. Due to their experience and broad knowledge of science, scientists are the ideal candidates for taking on this challenge. Sir Mark Walport said it best: 'Science is not finished until it's communicated' [4].

Let's rephrase our initial question. What is the best way for scientists to communicate findings with individuals outside their immediate area of expertise? Our experience at Youreka Science (Box 1) is that whiteboard videos are an effective way to engage in scientist-driven science communication. Moreover, the process of producing scientific whiteboard videos encourages conceptual thinking and clear, audience-appropriate communication – skills that every scientist can use not only to communicate with the public but to enrich teaching and training experiences and interactions with colleagues.

The Making of a Science Whiteboard Video

The key to producing a compelling video that will capture and retain loyal viewers revolves around three questions. What is the goal of the video? Who is my audience? How will I reach my viewers? You can refer to the accompanying video (see Video S1 in the supplemental information online) for instructions on how to produce a whiteboard video.

The first step in producing a whiteboard video is identifying a topic to provide the basis for writing a script. Remember the first question: what is the goal of the video? When writing a script, think about three points you want to get across. For instance, in a video describing the discovery of CRISPR, the goal is to explain the process and outcome of this new technology. Important points may include the following.

(i) How was CRISPR discovered and how does it work?
(ii) Why is it getting so much attention in the news?
(iii) What are the benefits and ethical issues associated with it?

We generally like to start with a provocative question, fact, or humorous anecdote. When writing the script, use a conversational tone, keep explanations simple, employ analogies, focus on telling the story of how this question came about and how it was answered, and avoid unnecessary details that may distract the viewer. It is important to provide context around the topic. In a video on CRISPR, you may consider explaining the limitations of previous genome editing techniques and how this new discovery pushes the field forward. One concluding style is to circle back to the initial problem and provide insight into the implications of solving this question for medicine and public health. We suggest writing a script of 500–600 words, which generally produces a video of 3–5 minutes. We have found that a whiteboard video of this length is very effective in capturing viewers and provides enough time to cover a complex scientific topic.

The main challenge to overcome when writing a video script is to foster the process of science in a digestible way. This can be particularly difficult when writing about a topic you are intimately involved with, such as a PhD project. Effectively, whiteboard videos challenge the creators to distill content in a way that captures the essence while maintaining the accuracy of the initial work. Asking friends or family members to read your script and developing your 'elevator pitch' will help you identify the key points that will guide the logical flow of your script and make it more accessible [5]. It is also important to always remember who the audience is. The general rule of thumb is this: when communicating science to the general public, write in simple terms and avoid acronyms and jargon. If you communicate in such a way that your audience will be able to convey the message to others, you will have truly succeeded in your mission.

Once the script is of the proper length and scope, grab a blank piece of paper and use colored pens to draw out each scene you are envisioning for the video. Use the power of the visuals to clarify and supplement the script, providing analogies and using color coding. Consulting with an artist who has some background in the sciences can be an effective springboard for looking at your content from a fresh perspective and can help generate new ways to visualize the science.

Once the script and storyboards are finalized, it is on to filming, voice-over recording, and editing. Frequently, the video is accelerated to match the audio piece and cover more content in less time, so do not fret about the speed at which you populate the whiteboard. The last important piece that must not be understated is distribution. How will I get my video in front of the right audience? Do not get discouraged by the millions of views a cat video will receive and the several hundred or, if you are lucky, thousands your first science video will capture. The availability of great science content does not necessarily mean people will use it. Collaborating with an advocacy group is a great way to distribute content to those committed to the topic. At Youreka Science, we will gladly share and promote any high-quality science video.

Learning from the Viewers

Videos provide live metrics to track audience retention, giving the creator the ability to modify their process to fit the viewer's needs. Youreka Science has produced over 40 videos describing new scientific discoveries, complex public health topics, and the process of drug discovery.