

Communicating chemistry for public engagement

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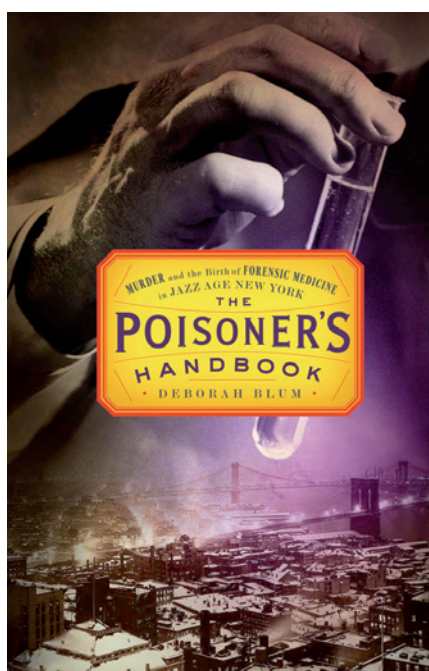
The communication of chemistry to wider society is difficult because of 'chemophobia', its inherent complexity and its lack of unifying grand themes. To engage with citizens about the benefits and related dangers of the field, chemists must improve their dialogue with broader sections of the public — but how?

When Pulitzer Prize-winning science journalist Deborah Blum wrote *The Poisoner's Handbook* (2010), which described the evolution of forensic science in 1920s America, she proposed as its subtitle: 'A True Story of Chemistry, Murder and Jazz Age New York'. But when the book was published, its subtitle was 'Murder and the Birth of Forensic Medicine in Jazz Age New York'. Blum explained the reasoning behind the title choice: "The Penguin sales team said that the word chemistry on the book's cover would tank sales".

It's not that chemistry is too intellectually challenging for wider audiences. Bestselling books on complex, specialized scientific topics published in 2010 included Rebecca Skloot's *The Immortal Life of Henrietta Lacks*, which covered the biology of cancer, to Stephen Hawking's *The Grand Design*, which detailed the physics of the universe's beginnings, and Sam Kean's *The Disappearing Spoon: And Other True Tales of Madness, Love, and the History of the World from the Periodic Table of Elements* (note that chemistry is not mentioned explicitly in this title).

It seems that, paradoxically, books about chemistry need to avoid mentioning it in order to be popular. This is symptomatic of what chemist and popular science writer Pierre Laszlo termed 'chemophobia' on the part of the public¹, with the popular associations of the field, according to the editors of *The Public Image of Chemistry*, ranging from 'poisons, hazards, chemical warfare and environmental pollution to alchemical pseudo-science, sorcery and mad scientists'².

This often-pejorative connotation of chemistry is partly a consequence of its history. Steve Miller, a chemist and planetary scientist at University College London, and co-author of *Science in Public* (1998), noted that "during the nineteenth century, there was great excitement in the results of



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chemistry — dyes, drugs, new materials — that carried on into the early twentieth century. Perhaps the turning point was the First World War, often termed The Chemist's War, in which dynamite, high explosives and poison gas took such a terrible toll. That very much coloured public perspectives on chemistry".

Other twentieth-century controversies followed. Lasting damage to the reputation of chemistry was caused by the thalidomide scandals, the Bhopal catastrophe and the pollution of both the Rhine in Europe and Love Canal in the US. The reaction of the chemical industry to some events often compounded the controversy: some chemical lobbyists tried unsuccessfully to smear the credibility of Rachel Carson after her book *Silent Spring* (1962) described the environmental consequences of pesticides, particularly DDT — and similar instances occurred with Nobel-winning Rowland and

Molina after they published their study on CFC destruction of the ozone layer¹.

Communicating chemistry in contemporary culture, where the historical associations of chemophobia exist alongside a dependence on the products of chemistry, is challenging and complex; there is no guaranteed formula for success. A suitable metaphor for thinking about how to communicate chemistry is retrosynthesis: a chemist starts with their target audience and the desired outcome of their communication and works backwards, without assumption, to design the most appropriate communication strategy. To do this, we argue that chemists should move from viewing communication as being solely about improving scientific literacy to seeing it as a means of engaging audiences with their work. We argue that vague notions of a 'general public' should be understood more as a collection of different segments of the public, or different publics, each with its own values, knowledge, beliefs and motivations. Moreover, we argue that chemists should draw on the reservoirs of knowledge from research in science communication to better communicate their work in a way that fosters trust, builds relationships and creates a dialogue with multiple audiences — in a contemporary communications landscape that is social, pluralistic and participatory.

Challenges in communicating chemistry

Aside from chemophobia, the communication of chemistry faces several obstacles. Chemistry itself is a fundamentally difficult subject. For someone who has not immersed themselves in the field, it is not easy to develop a feel for how chemistry works. Take, for instance, chemists' reliance on molecular structures to communicate. To the initiated, a chemical structure is a wealth of information contained within an efficiently minimal package; each structure has chemical properties implicit to its representation.

With the structure being a chemist's primary form of communication, how can the non-chemist be expected to understand?

The field is also marked by complexity. And although chemists and those who admire chemistry may find beauty in this complexity, it is easy to see why some non-chemists find the science capable of producing results that seem patently absurd. Take two different plastics, for example. Polyethylene and polyvinyl chloride are both polymers. They have the same basic repeating structure. The difference between the two is that the constituent monomer that makes up polyvinyl chloride has a chlorine atom where polyethylene has a hydrogen atom. The size difference between these two atoms is incredibly small. The atomic diameter of chlorine is larger than that of hydrogen by 150 pm. On an atom-by-atom basis, this difference seems hardly worth noting. Yet, when strung together into long polymers the difference between a flexible, transparent plastic water bottle (polyethylene) and a rigid, opaque PVC pipe (polyvinyl chloride) couldn't be more obvious. Admittedly, there is more to the processing of these polymers than discussed here. However, this is the appearance to someone looking at water bottles and PVC from outside the world of chemistry and materials science.

Global climate change is another example of an outwardly absurd effect of chemistry. Observed increases in surface temperatures on a global scale (diameter $\sim 10^7$ m) can be linked to several specific molecules (diameter $\sim 10^{-10}$ m). To compound this contradiction, the effects of climate change are measured in terms of years ($\sim 10^7$ s) even though molecular vibrations, which occur on a timescale of 10^{-15} s, are responsible for the warming effects. The fact that these observations and correlations are correct doesn't make them any less bizarre.

Moreover, chemistry is an insular field. Articles in research journals are written in a necessary jargon in which the latest in a string of incremental research is described. Historically, once chemical formulae became established, Steve Miller noted, "chemists were so pleased with themselves that they forgot they had made their subject seem more distant, more remote, more arcane to others". Most chemists do not actively work on communicating their research in ways that are approachable to non-specialists. There are several valid reasons for this. There are no pressing reasons for most research to be broadly communicated. Absolute truths are difficult to come by. The nature of the chemist's day-to-day work shies away from speaking in terms of blockbuster, field-resaping paradigm shifts.

Furthermore, according to the Stanford University chemist Richard Zare, "scientists who do speak to the public are considered by other scientists to have lost their way as to what is really important" — despite more than two decades of political imperatives in the UK and Europe urging scientists to communicate with non-specialists³⁻⁵.

Chemistry, furthermore, has no single idea that unites the field. Science writer Philip Ball noted that the chemical bond, "the glue that makes the entire discipline cohere", is one of several "convenient (and contested) fictions, such as electronegativity, oxidation state, tautomerism and acidity"⁶. Elsewhere, Ball argued that because of this lack of disciplinary unity, there has been little chemistry-focused fiction, popular science writing, television programmes and cultural debates — compared with physics, biology and mathematics. He wrote that chemistry, a science of synthesis, "seems to have little to offer in the way of grand themes"⁷. Evolutionary biology and cosmology, by contrast, were particularly suited to storytelling, as narratives were an intrinsic part of their disciplines, and their science usually had a philosophical dimension⁸. This lack of unification was seen also in the results of an informal online poll taken by *Nature Chemistry* of their Twitter followers to find out who they thought was the most important chemist of all time. There was no clear consensus (although Pauling came out on top). Compared with the agreed-upon greats of physics and biology (Newton and Einstein, and Darwin, respectively), chemistry has had a much broader collection of heroes.

Scientific literacy to public engagement

Communicating chemistry involves much more than chemists and their organizations adopting a particular communication style. It involves them rethinking their current style with respect to the historically dominant model of science communication to the general public, known as the scientific literacy or deficit model approach. Communication, in this model, is viewed as a linear process of transmission in which the scientific community corrects the apparent knowledge deficiency of a public who do not know enough science to value it and to discuss it rationally⁹. Furthermore, scientific facts are often assumed to be self-evident, speaking for themselves, interpreted similarly by different citizens. But, should citizens choose not to accept these facts or not to interpret them as scientists do, then this lack of understanding is characterized as a communication failure, blamed on journalists, communication professionals or a public that is viewed as irrational. These deficit model assumptions



have been challenged by the conclusions of several decades of empirical studies from science communication, which agree that an audience's values, ideology, religious identity, existing knowledge and perceptions of risk all contribute to their opinion of science. Following on from this work there has been a movement away from deficit approaches towards more effective science communication initiatives aimed at fostering trust, dialogue, relationships and participation. These approaches have been classified as dialogic or public engagement models of public communication¹⁰.

Such public engagement on chemistry, however, should not be confused with purely self-promoting public relations exercises. Rather the opposite in fact: it involves ensuring that chemists do not provide "a falsely benign image of the world — where chemical plants are only associated with the production of goods that yield 'better living through chemistry' and never with the realities of chemical pollution and toxicity"¹¹. And there has been an unfortunate tendency for chemists to avoid addressing these darker aspects of their field. Nobel Prize-winning chemist Roald Hoffman noted: "We don't have the very small and the very big. But we have molecules on the human scale, complex enough to hurt us and heal us. There is an internal fear in our community in talking about the 'hurt' part above. That's a mistake."

Rather, chemists and chemical organizations should focus their communication efforts on building what Rick Borchelt, special assistant for public affairs, National Cancer Institute, in the US, has called 'the trust portfolio', where communication between science and its various publics is open, two-way and transparent, in which non-scientists are



actively involved in decision-making about the regulation, funding and direction of scientific research¹². Yet dialogue approaches have not entirely replaced deficit approaches to public communication. Chemists, and scientists in general, are used to presenting their work and allowing their results to speak for themselves. Converting to a new style of communication is not trivial and it can be confusing knowing just how to approach a non-specialist audience with new chemical information.

But while many chemists are not keen to step forward and engage with broader audiences, chemistry risks becoming completely cut off from society. Removing the field from public discourse through a lack of engagement will imperil chemistry and be detrimental to civilization. Conversely, a public that is better equipped to join in chemically relevant debate is undoubtedly beneficial. This is clearly important when considering arguments such as those put forward by Roald Hoffmann in his book exploring the sociological and philosophical dimensions of chemistry, *The Same and Not the Same* (1995). He said that, as experts in the profession of molecular pursuits, chemists do not have a mandate to make decisions on the risks and benefits of the molecules they create¹³. Citizens and elected officials have this mandate, which chemists should help to inform. A public that is better able to accurately scrutinize the endeavours of chemists is a benefit to those professionals (who are dependent on their support for funding) as well as society at large. A recent example of the success of such public engagement is the Science is Vital campaign in the UK, which was organized in response to the announced cuts in the governmental funds for science during 2010. Impressively, the campaign showed how effective

communication can organize scientists, and mobilize enthusiastic non-scientists in the pursuit of persuading policy-makers.

Importantly, policy and social debates that involve chemistry (revolving around terms that include budget, the environment, human health and innovation) need to involve chemists. As Tim Radford, former science editor of the *Guardian* newspaper in the UK, has noted in his recent commentary in *Nature*, scientists can and should be the ones leading the way communicating their field¹⁴. Chemists have an innate grasp and feel for the ways and the wonders of molecules. Who better to communicate this passion and intimacy than those who practice it daily? And here scientists have an enormous advantage in communication — they have a large amount of cultural authority and public trust. A 2010 survey found the majority of citizens in the 27 member states of the European Union — 63 per cent — agree that scientists working at a university or government laboratory are best qualified to explain the impact on society of scientific and technological developments¹⁵. The next best qualified, for citizens, are scientists working in industrial laboratories. In the US, citizens believe that science leaders discussing public policy issues are relatively knowledgeable, impartial and should be relatively influential¹⁶.

Strategies for communicating chemistry

There are many approaches that can be used when relating scientific information. Depending on the context of each piece and the audience to whom this information is being presented, a strategy can be designed based on the strengths and weaknesses of different communication approaches¹⁷. Building on ideas of public engagement, there are established techniques from

communication studies that can be applied to communicating chemistry. We offer the following five strategies for chemists to consider in their communication efforts:

Practice research-driven communication.

Chemists can draw on decades of evidence-based and hypothesis-driven research from communication studies and science communication, which has historically a strong focus in the field on public attitudes, media coverage of science and the communication of contentious science-policy issues. Borchelt advises that established formative social science research techniques, including focus groups, surveys and interviews, could be used to identify various publics and understand how these publics acquire information¹². Evaluative research can be used to test the effectiveness of communication messages, approaches or techniques, before and after communication campaigns. Overall, this research should aim, not just to determine an audience's knowledge of chemistry, but also their attitudes, values and beliefs that affect how they view the field or topic being communicated.

Understand the audience. Part of this social science research involves understanding the various audiences for chemistry. These audiences are complex, but previous research has identified some ways of categorizing them for scientific information that can be applied to chemistry. Taking climate change as an example, there are 'issue publics' consisting of diverse small groups of people that are extremely concerned and informed about climate change and environmental issues, based on their values and identities¹⁸. There are also broader audiences that are inattentive to climate change, but might be exposed to the issue while consuming information after a major focusing event, such as the 2010 Gulf Oil spill¹⁹. These broader, inattentive audiences might also bump into climate change information while searching for other content, including entertainment media²⁰. The broadness of the field of chemistry, with its varied areas of focus, means chemistry is potentially able to connect on topics of concern to members of these various publics.

Participate in the new communication landscape. Chemists are communicating in a contemporary communications environment that is pluralistic, participatory and social. The traditional gatekeeper role of the science journalist as privileged conveyer of specialist information to general audiences has weakened. Journalists and scientists, readers and critics, professionals and amateurs, are simultaneously producers and audiences of science content. Chemists are using blogs

and other social media to communicate their work and agendas directly with various publics. Chemistry organizations are creating their own publishing platforms to reach the audiences themselves. Chemists, furthermore, can be part of an increasingly collaborative relationship that journalists are having with their audiences²¹. Blogs aimed at non-scientists are a great entry point for reaching a broad audience (and also a useful way to hone general writing skills, which has an importance for grant applications that cannot be understated). Well-written blogs aimed at chemists have the potential to reach a large section of the profession and initiate very important discussions within the community, as Derek Lowe's In the Pipeline blog does so well. The popular Periodic Table of Videos has justifiably become very popular with both chemists and non-chemists alike, and is an example of how alternative media are sometimes the best ways to inform and entertain.

about chemistry should be related in terms of human impact and interaction where possible. Because the fruits of chemistry touch and impact the everyday lives of humanity in a way that would seem to surpass the research done in other sciences, the field has some significant leverage in terms of communicating to non-chemists. Deborah Blum notes that chemistry is not just "the story of some weird experiment done in a distant lab. It's the story of dinner or something equally ordinary and therefore important". Steve Miller echoed: "I do think you have to tie chemistry to 'something'. In my case, that something is astronomy and planetary science. If you can tell an interesting story of the 'how we got to here from there' type, then I think people will read about chemistry — at least I hope they will". And Miller noted that "books trying to popularize chemistry — for example, those of Peter Atkins — concentrate more on chemical outcomes, and where we find those outcomes, in foods, drugs, plastics etc, than they do on the actual business of chemistry itself, which is the making of those foodstuffs, drugs and plastics from much simpler starting points". In addition, many have called for greater emphasis on chemistry studies inquiring as to the origin of life or for the drive to create materials for green energy that can replace fossil fuels.

Frame key messages to prompt engagement. Chemistry is a broad, complex field and cannot be communicated in its entirety in a single initiative, so chemists must learn to focus on framing their messages in ways designed to encourage public engagement. Within communication studies, frames have been defined as interpretative storylines that explain why an issue is important in societal debate²⁴. Frames work to distil complex issues by stressing some perspectives, arguments and considerations over others, stating why an issue might be a problem, who might be responsible and what solutions are needed²⁵. For example, public attitudes to nanotechnology vary depending on its applied context: energy applications are viewed more positively than those applications focused on health and human enhancements²⁶.

Summary

The most successful communicators of chemistry might use a combination of these approaches simultaneously. This is a significant task, especially as it is impossible to predict in advance which strategy will be the most effective. However, one principle remains certain: effective, engagement-focused communication is an ongoing process, continually refined,

tested and improved, re-thought anew after each initiative, building on previous efforts. As in retrosynthesis, chemists have more than one way to achieve their communication aims. Just as E. J. Corey developed retrosynthesis to achieve a target molecule "without any assumptions with regard to starting materials" (Nobel Prize Lecture, 1990) chemists must leave behind their preconceived notions for their preferred forms of communication. They must focus instead on the goals that they hope to achieve. And much like retrosynthetic methods, adoption of these new communication techniques by the chemistry community will open up a world of possibilities for developing a fuller relationship with society. □

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Communication by scientists in this new media environment can also inform wider debate on scientific issues. The coverage surrounding the publication in *Science* of a paper reporting bacteria that had incorporated arsenic into their DNA²² is an illustrative, and cautionary, example. The study garnered plenty of anticipation after it was heavily promoted by NASA but was subsequently critiqued online by scientists, non-scientists and journalists²¹. Its authors, having initially removed themselves from discussing its contents outside the peer-reviewed arena, eventually responded to the critical comments in two announcements on the personal website of the study's lead author, Felisa Wolfe-Simon²³. Contemporary and future scientific results that solicit a broad public audience must be willing to fully adapt to the contemporary media landscape with its multiple platforms.

Tie chemistry to society. Audiences are likely to be interested in chemistry topics that are connected to wider social issues or broader themes. Therefore, communication