Journal & Proceedings of the Royal Society of New South Wales, vol. 152, part 3, 2020, pp. 327–331. ISSN 0035-9173/20/030327-05

Bang! Crackle! Pop! Fizzle? — Chemistry outreach and fireworks

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Abstract

Chemistry is regarded — primarily by chemists — as the central science. Advancements in chemical knowledge have propelled developments in biology, physics, engineering, and medicine that now define our modern era. But chemistry has a significant image problem, with many public fears and misconceptions regarding the prevalence and uses of chemicals, and the roles of chemists in society. In my science communication practice, I endeavour to highlight and explain the everyday roles of chemistry. This may be through descriptions of the chemistry of commonplace objects, or through dramatic chemical reactions on fast timescales. Fireworks provide a unique opportunity for both approaches, as they are integral to many cultural celebrations and childhood experiences, but few people understand or appreciate the fundamental chemical principles at play in each pyrotechnic. Herein I have outlined my science communication practice, engagement strategies, and interrogate the challenges of measuring the outcomes of science engagement.

Introduction

Chemistry is often referred to as the central science as it bridges the biological, life, physical, and applied sciences. This position within the academic literature is clearly reflected from the citation metrics of academic publishing, with analyses of cross citations between over 16,000 journals indicating chemistry is highly interconnected to the other sciences (Börner et al., 2012). The standing of Chemistry with members of the public is less clear, and the "Decadal Plan for Australian Chemistry," published by the Australian Academy of Science, noted the general perception of chemistry to be negative (National Committee for Chemistry, 2016). Unfortunately, when most Australians think of the word "chemist" they likely think of someone selling medicines, vitamins, sunglasses, or perhaps jellybeans at a multicoloured warehouse. A 2015 report entitled "Public Attitudes to Chemistry," commissioned by the UK's Royal Society of Chemistry, found very poor recognition of chemists and chemistry as a profession and discipline of study respectively (TNS BMRB, 2015). The top 5 responses to the question "When I talk about a chemist what comes to your mind?" were: pharmacies/pharmacists; medication/medicines; prescriptions; drugs/tablets/pills; and shop/chemist's shop, while the responses to the question "When I talk about chemistry what comes to your mind?" were: school/teachers; science; chemicals/elements; drugs/tablets/pills/medication. These responses highlight the significant disconnect in the recognition of the chemical sciences as an essential influence on our modern lives, with clean water, synthetic materials, fuels, batteries, pharmaceuticals, and more relying directly on research, development, and manufacture by chemists.

An additional problem is the rise of chemophobia, where all manner of chemicals are vilified, including, but not limited to, gluten, fluoride, fats, sugars, nebulous "toxins", and more. This mistrust of chemicals has led to an increase of products promoted as "chemical free", from garden products, barbecue fuels, cleaning products, personal care products and more. To a chemist, "chemical free" is a complete misnomer as everything we interact with in our daily lives is made of chemicals. The ease of falling into the trap of chemophobia is highlighted in the infographics of James Kennedy, as illustrated in Figure 1, where the components of a commonplace object, such as a banana, are listed in full detail (Kennedy, 2013). To the uninitiated, this extensive list of chemicals, expressed in their full nomenclature, is challenging at best and terrifying at worst, however, this chemical cocktail is essential to make a banana a delicious and nutritious banana.

Alongside the rise of chemophobia is the decreasing engagement of students with high school mathematics and science subjects. A 2014 report highlighted the continuing decline of enrolments across mathematics and science in Australia, with perceptions of difficulty and usefulness identified as the most likely causes of the decline (Kennedy, et al., 2014). These diminishing enrolments will inevitably lower the scientific literacy of the general public. This decline runs concurrently with the continuing refusal of politicians to accept (and act) on the science of anthropogenic climate change as an imminent threat to our climate and ecosystems. The decline in scientific literacy, and continuing science denial has an immense impact on public trust in science. Serious questions are then raised regarding the social license of science, and highlight the need for scientists to build public trust in science and technology (Leach et al., 2019).

Figure 1: An All-Natural Banana — a chemophobe's worst nightmare (Kennedy, 2013). Image reproduced with permission from James Kennedy.

Fireworks?

Where and how do fireworks fit into this picture? The definition of a firework is a device using chemicals that when lit emits coloured flames, whistles, bangs, or sparks which can be made to rocket high into the sky before exploding, used for entertainment or celebration. Looking at this definition we can see some clear motivations for using fireworks to promote an interest in chemistry. First, they are used for numerous cultural and entertainment purposes, and many people have strong childhood experiences and memories of fireworks. Second, the chemical components are fundamental to the properties that are displayed and can be used to explain the chemical principles on a rapid timescale. To this end, I have developed a lecture featuring chemical demonstrations where the components of fireworks are highlighted through explanations and demonstrations of the fundamental reactions in a lecture theatre (Figure 2). The lecture is followed by professional fireworks featuring commentary on the individual pyrotechnic effects, followed by a 10–15 minute display.

There are numerous chemical demonstrations that can be made to highlight everyday objects and the chemistry they share with fireworks. This can begin with the simple chemistry of lighting a match, where components on the box and on the match head combine to give the desirable property, namely the safe and timely ignition of the match (Kilah, 2019). This chemistry can be demonstrated safely and explained in depth, and then related to other familiar objects such as party poppers (with similar chemistry to matches) and sparklers (incorporating metals and oxidants).

Figure 2: A chemical demonstrations performed at "The Periodic Table of Fireworks". Left to right: Chloe M. Taylor, Nathan L. Kilah, Adrian V. Wolfenden. Image reproduced with permission from Tayla Chick.

Slowly more chemistry can be introduced including chemical reaction schemes for the combustion of gunpowder, and the colours from the individual metal salts added to pyrotechnics. Having discussed and demonstrated the components of the firework, the nuances of the environmental impacts of fireworks can be discussed, specifically around issues of chemical pollution, and the prudence of fireworks during increasingly long bushfire seasons. The lecture also provides a platform to share a very strong safety message, as there are many risks to be managed with the chemical demonstrations and fireworks more broadly.

Target audience

So, who is the target audience for this show? My employer might hope for soon-to-be school leavers to be enrolled into degree courses in the next couple of years. However, it is my opinion that it is too late to motivate students in science and chemistry at such a late stage. My target audience is younger children around 8 to 12 years old who are more open to suggestions and encouragements towards new areas of interest. In reality, my fireworks event attracts a diverse audience of young families, parents with older children approaching university age, and significantly older attendees.

How does one seek to judge the success of such an outreach event? First and foremost is the need for the event to operate safely, with no incidents or concerns in the lecture theatre or at the outdoor fireworks display. Surveys have been considered as one approach to investigate the outcomes of the event, but how does one ask appropriate questions to gauge success? Survey instruments are increasingly used to understand the impacts of outreach (Vennix, 2018, and Wahono, 2019), but they are often narrowly defined to ask specific questions on desired outcomes, and avoid overwhelming the audience with myriad survey questions. And what would one ask for my firework event? Is this science outreach as a form of entertainment? As inspiration? As education? Or as student recruitment? Should success be judged by how many students show up to my lectures in the near or distant future as newly enrolled students? Attendees may also remember an obscure fireworks fact, but has that changed their perspectives on chemistry and chemicals? Thus far a single overarching focus of success has not been settled, and the best way to measure engagement remains unclear.

Looking for multipliers

One important lesson that I have learnt from undertaking this science outreach event is the need to look for multipliers from the input of a single activity. One theme or topic, once well research, can be communicated in many different ways to reach many different audiences. For example, the firework event has been run twice with over 700 attendees resulting in: interviews on nine radio programs; an article for The Conversation on the chemistry of lighting a match (Kilah, 2019); a published chemical demonstration which was developed during the planning of the event (Wolfenden and Kilah, 2017); and most recently an article in COSMOS magazine (Kilah, 2019a). Each of these activities has allowed for the same message to be communicated to many different audiences, from the casual radio listener, through to academic audience, and highly motivated science readers.

Conclusion

Fireworks are an effective outreach technique, but they can only ever form a small part of the need to communication chemistry to the general public. The curator and artist Kirsha Kaechele (of Hobart's famous Museum of Old and New Art) once presented at my institution on the topic of science communication. To paraphrase her conclusion, a member of the general public's impression of science is like a digital photo — it is formed by a number of pixels. Any one science communication activity can only ever be a single pixel in that image. Therefore, when engaging the public with science communication make sure your pixel is bright.

Acknowledgements

I thank The University of Tasmania, Inspiring Australia, and the Royal Australian Chemical Institute for their support of chemistry outreach events leading to this submission.

References

Börner, K., Klavans, R., Patek, M., Zoss, A. M., Biberstine, J. R., Light, R. P., Larivière, V., & Boyack, K. W. (2012), "Design and update of a classification system: The UCSD map of science" *PLoS ONE*, 7, e39464.

Kennedy, J. (2013) Ingredients of an all natural banana. Retrieved 10 March, 2020, from https://jameskennedymonash.wordpress.com/2013/12/12/ingredients-of-an-all-natural-banana/

Kennedy, J., Lyons, T., Quinn, F. (2014) "The continuing decline of science and mathematics enrolments in Australian high schools" *Teaching Science*, 60, 34-46.

Kennedy, J. (2019). *Fighting Chemophobia: A survival guide against marketers who capitalise on our innate fear of chemicals for financial and political gain*. CreateSpace Publishing, Scotts Valley, California, USA.

Kilah, N. L. (2019), "Curious kids: when I swipe a matchstick how does it make fire?" *The Conversation*. Retrieved 10 March, 2020, from https://theconversation.com/curious-kids-when-i-swipe-a-matchstick-how-does-it-make-fire-116673

Kilah, N. L. (2019a) "The science of fireworks", COSMOS, The Royal Institution of Australia Inc., Adelaide, Australia, 85, pp. 102-106.

Leach, J., Herington, M., Raman, S. (2019), "Scientists want to build trust in science and technology. The alternative is too risky to contemplate." *The Conversation*. Retrieved 10 March, 2020, from https://theconversation.com/scientists-want-to-build-trust-in-science-and-technology-the-alternative-is-too-risky-to-contemplate-116269

National Committee for Chemistry. (2016), *Chemistry for a better life. The decadal plan for Australian chemistry 2016–2025*, Australian Academy of Science, Canberra, Australia.

TNS BMRB (2015) "Public attitudes to chemistry — research report" Retrieved 10 March, 2020, from https://www.rsc.org/globalassets/04-campaigning-outreach/campaigning/public-attitudes-to-chemistry/public-attitudes-to-chemistry-research-report.pdf

Vennix, J., den Brok, P., & Taconis, R. (2018) "Do outreach activities in secondary STEM education motivate students and improve their attitudes towards STEM?" *International Journal of Science Education*, 40, 1263-1283.

Wahono, B., & Chang, C-Y. (2019) "Development and validation of a survey Instrument (aka) towards attitude, knowledge and application of STEM" *Journal of Baltic Science Education*, 18, 63-76.

Wolfenden, A. V., & Kilah, N. L. (2017) "Ancient alchemy in the classroom: a honey-based, deflagrating pyrotechnic" *Journal of Chemical Education*, 95, 1350-1353.