Gases in the Air: A science demonstration assembly for primary schools

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Abstract

This article considers the place of science demonstrations for science communicators and teachers who wish to create effective primary science assemblies. Feedback from schools over a 3-year period is used to demonstrate the impacts on pupils and teachers of science assemblies (chemistry lecture demonstrations), given by appropriately trained science communicators, on pupils' (UK Years 1-6, ages 5-11) understanding of the Earth's atmosphere and climate.

The appreciation by teachers of using challenging concepts, correct terminology and in redressing teachers' own science misconceptions is highlighted. The enthusiasm shown by the pupils for live science demonstrations (not to be confused with chemical magic shows) is evidenced.

Keywords: Science communication, science demonstrations, school assemblies, raising aspirations

Introduction

The evidence for climate change is overwhelming (IPCC, 2019) and underpins the United Nation's Sustainable Development Goals (UN, 2019). Children are aware of a wide range of environmental issues, including air pollution and climate change and their importance and urgency. As part of the Bristol ChemLabS Outreach Programme from the School of Chemistry at the University of Bristol, the primary school talk *Gases in the Air* has been given (usually) to children and teachers in around 3000 (mainly UK) primary schools since 2008 (Tuah *et al,* 2010; Harrison & Shallcross, 2011a; Sunassee *et al,* 2012; Shallcross *et al,* 2013; Harrison & Shallcross, 2016a, 2016b).

The talk considers the gases in the air (Figure 1) and introduces the ideas of air quality and climate change. In this paper, we briefly describe the content of the talk and then use feedback from schools to highlight why it has been so effective (evidenced by awards, the number of schools that have engaged, feedback and other examples).

University (chemistry) Outreach programmes often use classic experiments, such as liquid nitrogen (often in the production of ice cream) and the production of a foam during the decomposition of hydrogen peroxide, often referred to as the 'Elephant's Toothpaste Experiment' (Harrison &

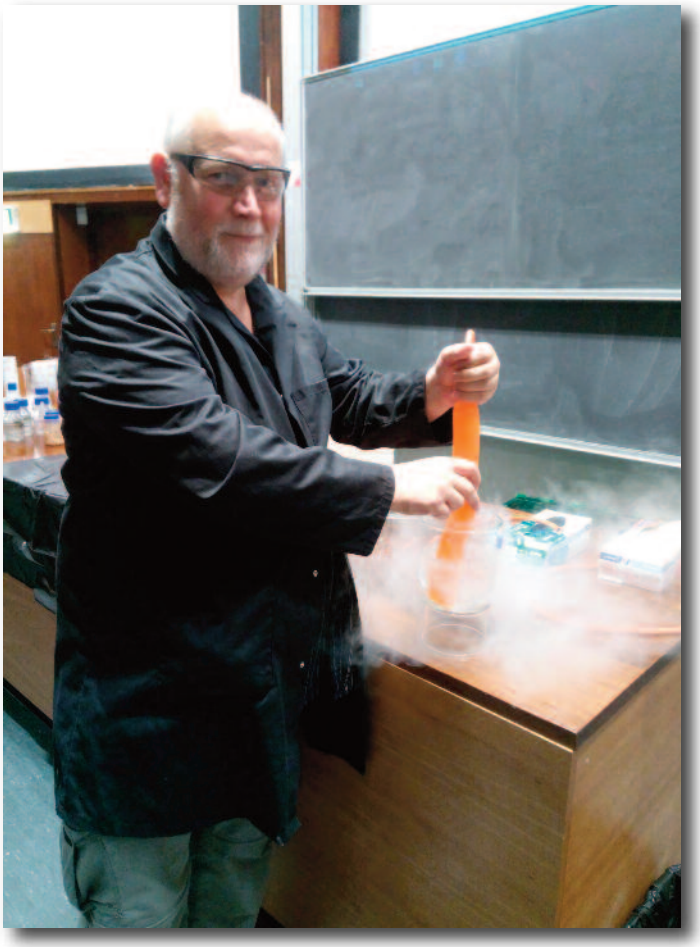

Figure 1. A typical experiment (balloon into liquid nitrogen) from chemistry demonstration talks by Bristol ChemLabS' Outreach programme.

Shallcross, 2016a; Pratt & Yeziereski, 2017, 2018a, 2018b, 2019), during outreach events to schools (see Figure 1). In a series of recent papers, Pratt and Yeziereski (2017, 2018a, 2018b, 2019) surveyed university students who were part of outreach programmes across the US and, whilst they believed that school student recipients were having fun, learning new ideas and connecting with scientists, the researchers discovered several science misconceptions amongst the university student chemist presenters and, as a result, some of their answers to questions were incorrect. In addition, their understanding of appropriate language, assumed prior knowledge, and appropriate use of analogy was shown to be problematic, whilst it was clear that primary school outreach posed additional communication problems to those considered at secondary school level.

Content of the assemblies: *Gases in the Air*

The talk uses a range of lively chemistry and physics demonstration experiments to discuss the different gases in the air. A range of liquid nitrogen experiments (Tuah *et al*, 2010; Harrison & Shallcross, 2016a) is used to discuss changes of state, reversible and irreversible change and observational skills, as well as to discuss the major gas in the atmosphere, nitrogen (N_2). Oxygen (O_2) is discussed using the Elephant's Toothpaste Experiment, i.e. the decomposition of hydrogen peroxide (Tuah *et al,* 2010), which also illustrates the role of a catalyst (Figure 2). The role of oxygen in respiration (not breathing) and in combustion is discussed, as is the production of oxygen from photosynthesis by plants (and not just trees). For carbon dioxide (CO_2), another major gas, solid CO_2 (dry ice) is used in a range of experiments that illustrate sublimation, the acidity of carbonated water (water with dissolved CO_2 in it, such as the oceans) and the process of neutralisation. The illustration of properties of the low-density gases hydrogen and helium, through their explosive and non-explosive nature, is memorable (a 'chemistry magic show'). The talk is in the tradition of storytelling (e.g. Dahlstrom, 2014), whereby it weaves a story around the demonstrations rather than just going through experiment after experiment. The longer version of the talk (given to secondary schools and the general public) is called 'A Pollutant's Tale' and demonstrates the strong emphasis on narrative. The audience are encouraged to participate where appropriate, are asked questions and are invited to make predictions throughout in keeping with the model found to be most effective for talks with demonstration experiments (DeKorver *et al,* 2014).

All outreach talks and, particularly, *Gases in the Air,* were devised by a highly experienced secondary school science teacher, who was the first School Teacher Fellow (Shallcross & Harrison, 2007a, 2007b; Shallcross *et al,* 2014) in the UK, working with a research academic expert here in atmospheric chemistry. Such a combination ensures that appropriate science language and concepts are used for the target audience, experiments used can be mapped to curricula and, because a teacher leads this activity, there is good overlap with other teachers whose schools are visited. Pre-visit materials and conversations can prepare the teachers for the visit and they can prepare their children. Like many programmes, Bristol ChemLabS works with postgraduate students (Harrison *et al,* 2011b) who are trained to deliver a wide range of talks. The issue of misconceptions for any deliverer is minimised, as a senior member of the team will work with and accompany a junior member until the former is confident that the talk is being delivered to the high standards set. Analysis of typical feedback allows the impact of the talk to be monitored.

Feedback from schools

Immediately post-assembly, the organising teacher is asked verbally for feedback on 'the impacts of the assembly on their pupils and/or teachers'.

Figure 2. The Elephant's Toothpaste Experiment.

This is followed up with an e-mail sent within 48 hours posing the same question. The consistent question and lack of formalised questionnaire allows for free response-style feedback. Some correspondents simply reply by e-mail; others add tweets and articles in school newsletters. Responses are typically sent within 2 weeks. Occasionally, pupil letters, used by some as a follow-up, are sent by post. These are not considered here. The feedback obtained over the 3 years of the project was then collated by dominant theme. Typically, feedback is positive, emphasising the excitement generated through the storytelling approach, the raising of aspirations, the longevity of the impact and the impact on children and teachers. Themes from feedback that provide insights into aspects of the talk are considered in more detail below, illustrated by representative examples from school feedback.

Explaining the science behind the experiments

It is not enough to carry out exciting experiments; the science behind them must be explained at the appropriate level and this requires expertise and effort to make it happen. The talk/science assembly/lecture demonstration has benefitted from much feedback and advice over the years, has been given in schools across the world and translates well. The issue of the presenter propagating misconceptions is addressed by using a highly experienced school chemistry teacher to deliver the talks, or to train/teach those delivering the assemblies so that misconceptions are not propagated:

'*Thank you very, very much for the most excellent show last week. I have never ever seen anyone do a whizz and bang type of science show* ***before, where they properly explain to the children in language that they can understand and use, exactly what is happening****. Amazing. Shows it is possible, and people like [named commercial groups] should hang their heads in shame. The children really, really loved it and learned masses* ***(and it was excellent CPD for the staff too)*** *and we will all remember it for a long time*' (Science Co-ordinator).

Some examples of misconceptions addressed in this assembly include:

- When asked what colour the nitrogen gas in the air is, pupils often answer in terms of transparency ('clear', 'see-through'), i.e. light passing through the air, rather than answering in terms of lack of colour – 'colourless'.
- Boiling and freezing: in everyday parlance, these terms are used to describe the weather. In science, they have precise meanings. 'Boiling' describes a liquid becoming a gas. Liquid nitrogen boils at a temperature 220°C below room temperature. A solid such as a metal coin is frozen, i.e. solid. Putting rubber tubing into liquid nitrogen cools down an already frozen (solid) material and changes its stretchy properties.
- The breakdown of the structure of expanded polystyrene with acetone is not a melting process, as no heat is used.
- Photosynthesis (oxygen production) is not just carried out by trees, but by all plants, including weeds, grass and seaweed.
- Fuels do not release energy. The combustion (burning) of fuels with oxygen releases energy (heat, light and sound), i.e. reactions release energy.

Knowledge, feedback and answering of questions

Asking and answering questions offers a chance for children to articulate and develop their knowledge. Skill in answering questions is important as the feedback below states, with the way in which the questions are answered (language, tone, etc.) being critical for the audience.

'He handled the questions from the children really well – the answers to some of the more obscure questions were interesting and well thought out. I particularly liked the way he picked up on the words the children were using. If they weren't scientific, he would let them know (giving them examples of words they could try instead)' (Accompanying teacher).

All the audience are engaged with challenging material

The audience of the assemblies is not solely comprised of children; teachers, teaching assistants and, occasionally, caretakers, school governors, administrators and carers/parents may also be in attendance. It is important that those in contact with the children post-assembly understand the content and, where necessary, adjust their own previous knowledge, to answer the inevitable pupil questions.

'I know that there are now children who have had their imaginations ignited as a result of the visit. The presentation was full of facts, figures and fun and

managed to keep Year R to Year 6 captivated – a real skill! X spoke about "CPD by diffusion" and I know that some of the teachers and other adults in the room were equally captivated by the possibilities presented' (Science Co-ordinator).

'Your impressive assembly was the highlight of our school's science week. All of the staff that attended have since commented on the additional subject knowledge that they gained from the session…It is an important part of all our jobs as science leads to instil in our children a love for science' (Science Co-ordinator).

Participants enjoy being challenged by the material presented and supported in their exploration of it. One of the constant issues raised about teaching science at primary school is teacher confidence (e.g. Murphy *et al,* 2007) and it is important that talks of this kind support staff's continuing professional development (CPD).

Raising aspirations and science as a potential career

It is often imagined that discussing science careers, or careers in general, with primary-aged children is neither possible nor effective. However, this is possible, is effective here and is welcomed by all school participants. Indeed, pupils leaving the assembly have often raised aspirations and want to tell the presenters that they now want to be scientists!

'…The show was definitely inspiring for the children: they can see science as something very exciting and hopefully very achievable. I loved the way you talked about the various careers that can stem from taking science as an academic subject as this gives it a purpose and places it in the real world' (Organising teacher).

*'…Many of the **children** have now **decided** that they are going to be **scientists**! ([Named pupil] says that he now knows which university he's going to go to!)'* (Organising teacher).

Talks of this kind make follow-up hard

There are support materials available but, as feedback below shows, school classes can reflect on the material covered themselves. The combination of fundamental science concepts in support of ideas about air pollution allows both teachers and children to explore further. Whether they are used, or how they are used, to expand the National Curriculum is determined by the teachers. The use of these materials has not been monitored.
'The visit was inspirational to the children. There has been a lot of talk since the assembly about gases in the air and all the classes did a follow-up session afterwards. Some classes wrote letters about what they discovered, others made posters and others made poems. All the teachers who attended the assembly have given their praise to the way it was presented to the children. It was very engaging and brought to life 'gases' in a fun and interactive way' (Organising teacher).

Fun and learning

Humour is one way of delivering materials to students: that is, assuming that the humour is appropriate. Instructional Humor Processing Theory (IHPT) hypothesises that humour related to content correlates positively with student learning, at least in higher education. It has been found that inappropriate humour has the opposite effect (Wanzer *et al,* 2010). From the teacher's perspective, this also applies to primary school children. The use of appropriate humour includes grabbing the attention of students, managing possible disruptive behaviour, creating a positive attitude to the topic, and reducing the anxieties that some have with potentially difficult topics (Ziv, 1988).

'The science show that X did was fantastic!!! Throughout the talk he made all aspects of what he was doing really interesting for all the children. The humour was perfectly pitched for them and that grabbed them and then, on top of that, there were bangs and explosions that made it even better' (Teacher).

'The whole school was buzzing for the rest of the day…It was pitched perfectly to the audience and challenged the children's science investigative skills as well as their knowledge. I particularly liked how you related it to things the children were familiar with so that they could relate to it all.

You always know when something has gone down well in schools when you overhear conversations in the dining hall about what sort of scientist/engineer the children want to be when they grow up!' (PSTT Fellow).

Change in science profile at a school

The poor status of science in some primary schools is often commented upon by organisers while the assemblies are being set up. It is pleasing that feedback indicates that such large-scale assemblies have given science teaching a boost in many of the primaries visited.

'*...The "gases in the air" demonstration has helped to boost the profile of science in our school and made all of the children excited and enthusiastic about science and its possibilities. Thank you, X!'* (Science Co-ordinator).

'*The children enjoyed the range of demonstrations carried out. Subsequently, we have gained a great deal of momentum in our science lessons, both in scientific thinking and in realising as staff and pupils how important it is to really hone down on using accurate scientific language to describe what we observe and hypothesise. Many thanks*' (Headteacher).

It is often said that talks with science demonstrations are easily forgotten and have little long-term impact. Our experience suggests quite the opposite: schools are using the talk to change the way that they teach science and using it as an inspirational launch pad for science in their school.

Summary

There can be much scepticism about science demonstrations for primary school pupils, with criticisms including 'helicoptering in' as being ineffective, follow-up being difficult for schools, poor use of appropriate science language and being perceived as a 'magic show' where exciting experiments are simply shown without correct explanation at an appropriate level for the audience. Through using appropriately trained science communicators and teachers, where vocabulary, the correct science theory and analogies, the relationship to everyday examples and, of course, health and safety considerations are addressed, these criticisms are overcome and pupils, teachers and other staff and stakeholders obtain a valuable learning experience that they will remember for some time. Our experience shows that it impacts on long-term learning, aspirations and confidence.

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