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**Article**

# 'Superbugs': raising public awareness of antimicrobial resistance through a pop-up science shop

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## Abstract

'Superbugs: A Pop-up Science Shop' was a public engagement event in the school summer holidays of 2019, organised by members of Cardiff University's School of Medicine. We transformed an empty retail unit in the centre of Wales's largest shopping centre into an interactive and immersive microbiology experience. We facilitated two-way dialogue to impart positive impact on the awareness of antibiotic resistance, while concurrently evaluating the efficacy of an engagement strategy focused on the utilisation of public spaces to attract public demographics diverse to those who would normally engage with conventional science, technology, engineering and mathematics (STEM) outreach. Over the course of 14 days, we welcomed 6,566 visitors, with 67 per cent attending as part of the natural footfall of the shopping centre. We created 1,626 young Antibiotic Resistance Champions, located in over two hundred schools, across many of the most deprived areas in Wales. We imparted a positive

impact to our stakeholders, with a significant increase in the knowledge and understanding of the subject of antimicrobial resistance (AMR); 91.7 per cent indicated that they had a better understanding after the event. In this article, we discuss the evolution of 'Superbugs' from concept, planning and design, to the logistics of delivering an engagement event of this scale. We focus in particular on the learning outcomes of the project, and on how this will shape the future of our 'Superbugs' project, and engagement events beyond.

**Keywords** antimicrobial resistance; antibiotic stewardship; education; public engagement with research; public spaces; public awareness; science engagement; STEM

### Key messages

- Creating a multidisciplinary core team is essential to the success of large-scale engagement events, as is the support and development of large numbers of colleagues/volunteers.
- Utilising themes of exhibition and gameplay alongside strong fear–empowerment messages is an impactful way to confer positive influence and behaviour around antimicrobial resistance (AMR) and the use of antibiotics.
- 'Pop-up shops' are an effective mode of delivery to capture diverse public demographics far beyond those who would traditionally engage with scientific outreach and science engagement.

## Introduction

Antimicrobial resistance (AMR) is among the most significant threats to global public health, food security and development (WHO, 2020). Infections resistant to multiple classes of antibiotics compromise patient treatment and carry significant economic burden. The spread of such infections is exacerbated by social and economic factors, including, but not limited to, the inappropriate use of antibiotics at a local, national and international level. Given the everyday implications for public health, social education and participation are paramount to the success of strategies to control the concerning rise of AMR worldwide. Society has a pivotal role to play through improved antibiotic stewardship, maintenance of good hygiene, vaccination, and the election and accountability of policymakers. Management of major AMR pathogens such as methicillin-resistant *Staphylococcus aureus* (MRSA) and *Clostridium difficile* has shown that public-focused campaigns around infection control and antibiotic stewardship can indeed result in reduction of infection rates (Ashiru-Oredope et al., 2012; Duerden et al., 2015). However, without adequate insight and basic understanding of infection control and antibiotic resistance on behalf of society, we cannot hope for success in programmes and initiatives aimed at combating the current crisis. The World Health Organization (WHO) Global Action Plan on Antimicrobial Resistance outlined Objective 1 of their strategic plan as 'Improve awareness and understanding of antimicrobial resistance through effective education and training' (WHO, 2015a: 8), testimony to the importance of public participation and understanding. On 24 January 2019, the UK government identified 'Engage the public on AMR' as one of their nine ambitions as part of their '20-year vision for antimicrobial resistance' (GOV.UK, 2019).

In conjunction with their action plan, the WHO published a 12-country snapshot survey, the *Antibiotic Resistance: Multi-country public awareness survey* (WHO, 2015b). Of those surveyed, 76 per cent incorrectly identified the statement 'Antibiotic resistance occurs when your body becomes resistant to antibiotics and they no longer work as well' as true, and 64 per cent incorrectly thought that the common cold and flu can be treated with antibiotics. Perhaps most concerningly, 72 per cent of participants agreed with the statement 'There is not much people like me can do to stop antibiotic resistance'. There are economic, geographical and educational caveats to many of the results presented in the report, but the picture painted is a stark one. Furthermore, this is not an issue limited to the lay public. Dyar et al. (2018)

report that, while 100 per cent of health-care students (predominately medicine, pharmacy, dentistry and veterinary medicine) correctly stated that bacteria could become resistant, more than 40 per cent incorrectly believed that humans and animals could also become resistant.

It is with active members of the AMR and infection research community, such as ourselves in the team that delivered the event 'Superbugs: A Pop-up Science Shop', that responsibility must lie. There is clearly inadequate and inefficacious communication of the AMR message, the research being carried out, and the role that society has to play, at a time when it has never been more pertinent – not only due to the grave consequences that the global AMR crisis has, and will continue to have, on mortality and morbidity, and the economic implications, but also to avoid the assuaging of impact of research within the field. It is through these frustrations, and a desire to contribute to the redressing of the balance, that our project, 'Superbugs: A Pop-up Science Shop', was born.

'Superbugs' was a proof-of-concept event, held in the school summer holidays between 29 July and 11 August 2019, open for all 14 days, between 9 a.m. and 5 p.m. The event aimed to combine the philosophies of public engagement with research, school outreach and science exhibition to deliver an interactive and immersive experience in a public space, outside traditional scientific and academic environments. The event utilised a vacated retail unit (approximately 2,400 ft<sup>2</sup> in size) in the public space of St David's, the largest shopping centre in Wales, and one of the busiest in the UK, and transformed the unit into a professionally designed interactive research experience involving laboratory activities, games, artworks, information sheets and competitions on the themes of bacteria, antibiotics and drug-resistant infections.

In this article, we explore in detail the process of conception, planning and delivery of the 'Superbugs' event. Further, we present much of the quantifiable output generated by our stakeholders and the project team, and how this learning may be of positive impact for AMR researchers, public engagement professionals and all organisations with a public engagement agenda.

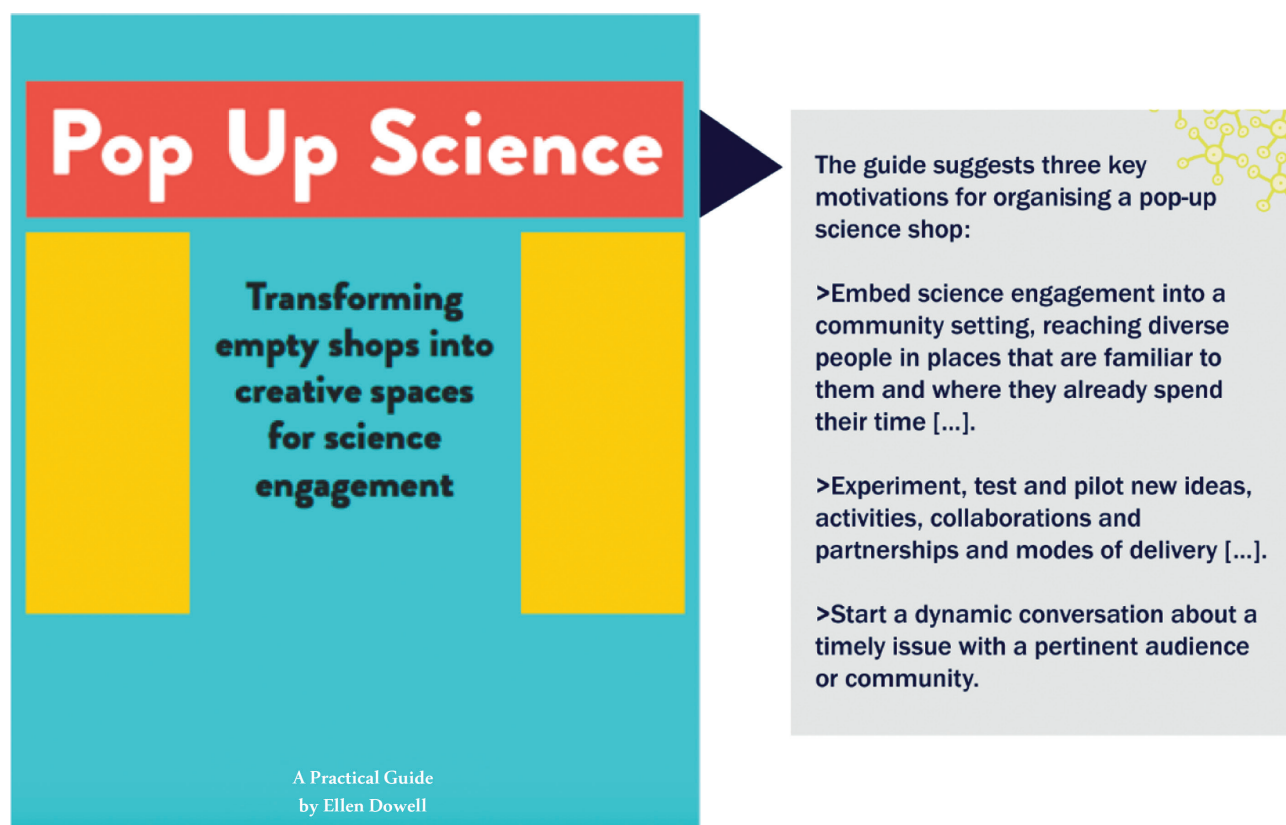
## Planning the project

The concept of 'Superbugs: A Pop-up Science Shop' originated from two earlier events. The first was the organisation of 'Superbugs: The End of Modern Medicine', a public engagement evening held at Techniquet, an educational science and technology museum in Cardiff (Cardiff University School of Medicine, 2018). Through feedback collected from visitors, it was here that the potential to deliver meaningful AMR messages through the medium of exhibitions, presentations, games and interactive laboratory tasks was first explored, which laid the foundation for the content developed for the later pop-up science shop. The second event was participation in the Cardiff University BLS (Biomedical and Life Sciences) Public Engagement Development Programme, through which we were introduced to the *Pop Up Science* report (Dowell, 2017; see Figure 1), and the potential of such a delivery model. Research by the British Science Association and King's College London has suggested that up to 76 per cent of UK adults (defined as age 16 and older), approximately 49 million people in total, do not participate in scientific outreach, either due to lack of interest or due to lack of effort to seek out such opportunities (British Science Association, n.d.). This highlights the space to further evaluate the impact of scientific engagement carried out in public spaces, and the engagement of the general public.

In their book *Public Space*, Carr et al. (1992) outline five important requirements that influence the appeal of public spaces for communities: (1) comfort; (2) relaxation; (3) passive engagement; (4) active engagement; and (5) discovery. It was the latter two, the need for mental and physical challenge (active engagement), and offering the chance to evolve new ideas and interests in unfamiliar topics (discovery), that were at the core of what we hoped to achieve in this project: as Carr et al. (1992) succinctly put it, 'enable the users' interest to endure'.

Our plans were collated into an application to the Wellcome Trust Institutional Strategic Support Fund (ISSF3) on the theme of Public Engagement Proof-of-Concept funding, with the proposed AMR

Figure 1. Key applicable points from *Pop Up Science: A practical guide* (Source: Dowell, 2017)



pop-up science shop as a novel delivery model that had not been utilised before at Cardiff University, nor to our knowledge more widely in the area of AMR. The overall aim of the proposed project was to increase the awareness and knowledge of the general public about the microbial world, infection biology and the increasing threat of antibiotic resistance to global public health. Additionally, we hypothesised that by taking the event into public spaces, we could evaluate the efficacy of attracting the attention of all public demographics, not only those that would traditionally attend scientific engagement events; in order to achieve this, we defined several underlying objectives (Table 1).

In September 2018, we were awarded Public Engagement Proof-of-Concept funding, and secured contingency funding and support from the Systems Immunity Research Institute at Cardiff University, where most of the funded team's scientists were based at the time. Cardiff University is the leading biomedical research institution in Wales, as evidenced by ranking fifth overall in the UK, and eighth in Clinical Medicine, in the Research Excellence Framework (REF) 2014 – the most recent nationwide impact evaluation assessing research at all UK higher education institutions – with its world-leading basic and clinical research on AMR, infection and immunity as a core strength.

## Delivering the project

### Multidisciplinary team and strategic partners

From an early stage, it was identified that a multi-skilled team from various backgrounds was vital to delivering the project successfully. A core team from across the School of Medicine was assembled, including AMR research scientists, public engagement champions and professionals, and a graphic

**Table 1. Logic model of 'Superbugs: A Pop-up Science Shop' (Source: Authors, 2022)**

**Overall aim:** To increase awareness and knowledge of the microbial world and antibiotic resistance

**Underlying objectives:**

- to reach new and diverse public demographics by taking science to the people
- to facilitate two-way dialogue of mutual benefit between scientists and the public
- to provide public access to information about local and international AMR-related research, how it impacts their lives, and further scientific–public engagement opportunities
- to create strategic relationships between Cardiff University, the public and supporting partners to facilitate an evolving and sustainable event.

Inputs	Activities	Outputs	Outcomes and impacts
Time of staff and volunteers	Interactive microbiology laboratory	Quantifiable data on attendance	Increased public knowledge about microbiology and AMR
Wellcome Trust ISSF Public Engagement funding	'Grow your own microbe' station (with online follow-up)	Qualitative feedback on public experience	Improve our understanding of efficacy of novel engagement approach, to inform best approaches with which to engage the general public and improve knowledge base
Support from partners (St David's, GiantMicrobes, Diverse Cymru)	Microscopy corner 'Create your own microbe' art corner	Gauge how the public/ children interpret the microbial world Evaluation report and journal publication	
Involvement of primary school children and parents in the development of 'Superbugs' content	Bacterial thought-tree for public opinions 'Token-system' benchmarking at entrance and exit Completion of 'Superbugs' stick cards	Creation of 'Antibiotic Resistance Champions' Television/radio interviews Increased followers on relevant social media accounts	Creation of sustainable relationship with partners Successful pilot event leading to external funding for evolved, sustainable event

designer. The benefit of this to the project was not only the wide spectrum of talents and knowledge, but also the network of contacts brought to the table by each core team member. In addition to this, two early career researchers were recruited to work with us in designing the AMR-related content for the shop.

Equally important to the success of the project were the strategic partners that we were able to engage:

- St David's – the largest shopping centre in Wales, based in the heart of the Welsh capital, Cardiff, with a footfall of approximately 750,000 per week. Management staff from St David's were involved in very early discussions about the viability of providing an empty unit within the centre, and they provided support to our funding application on those grounds.
- Morgans Consult – local signage and brand implementation specialists (<https://morgansconsult.com/>). Funding freed up by St David's was invested in further professional delivery of both the interior and exterior of the pop-up shop. Morgans Consult worked closely with the team to design and fit an exhibition bespoke for the retail space provided by St David's.
- Diverse Cymru – the only charity in Wales that focuses on all protected characteristics, to challenge discrimination and reduce inequality. Diverse Cymru provided us with an independent review, evaluating the performance of 'Superbugs' in meeting the needs of, and appealing to, stakeholders with protected characteristics.

- British Society for Immunology – provided enthusiastic support for the original application and project, alongside the promise of promotional and educational material for distribution at the event.

## Focus group for target stakeholders

To support and inform the planning stages of the event, a focus group was organised for key target stakeholders: families with children in Key Stage 2 (7–11 years old) and Key Stage 3 (11–14 years old). The meeting was held after school hours at Rhiwbina Primary School, Cardiff, and it was attended by seven families recruited through an invitation forwarded to parents by the head teacher of the school. Children were split into two groups and taken through several sample activities akin to what we hoped to deliver at the 'Superbugs' event. Concurrently, we facilitated a discussion with the parents on various aspects of the project, before eventually coming together to gather further feedback from the children. Box 1 summarises the discussion points taken from this focus group session, which played a key role in the evolution and direction of the project.

This approach proved to be an invaluable step in the evolution of 'Superbugs', not only by informing the final design schemes of the shop (and the popular visuals of microorganisms), but also by confirming that our planned activities were engaging not only to our primary target stakeholders, but also to those younger and older. To quote one inquisitive 4 year old after attending the focus group, 'looking at the little things in the microscope was my favourite'.

## Design concept and the importance of exterior design

A fundamental aim of 'Superbugs' was to evaluate the effectiveness and success of a pop-up shop in engaging lay stakeholders of all demographics, not limited to those who would traditionally seek out events related to science, technology, engineering and mathematics (STEM). Attracting the natural footfall in the public location of the shop was therefore imperative, and the investment of the project's time and finance in the exterior design of the shop reflected this. Figure 2 shows representative photographs taken before the transformation of the vacated retail unit (previously a Clarks shoe shop, with shelving and lighting still in place), and during the 'Superbugs' event, to illustrate the changes to the interior and exterior design of the shop.

The origin of the 'Superbugs' design lies in promotional material developed for the Systems Immunity Research Institute, including a bus-stop poster and social media campaign (Systems Immunity Research Institute, n.d.). The illustrations were created to represent the diversity of microorganisms that

### Box 1: Significant output from the stakeholder focus group

#### Marketing and advertisement

- Overwhelming preference for a more colourful, less 'corporate' design, which will appeal more to families and young children
- Make obvious the flexibility in terms of how much time visitors need to spend on the experience
- Use social media (increasingly influential for family units)
- Use local advertising forums (Cardiff TV, *Primary Times*, Mummy Says blog, other social media)

#### Attractive features that should be included

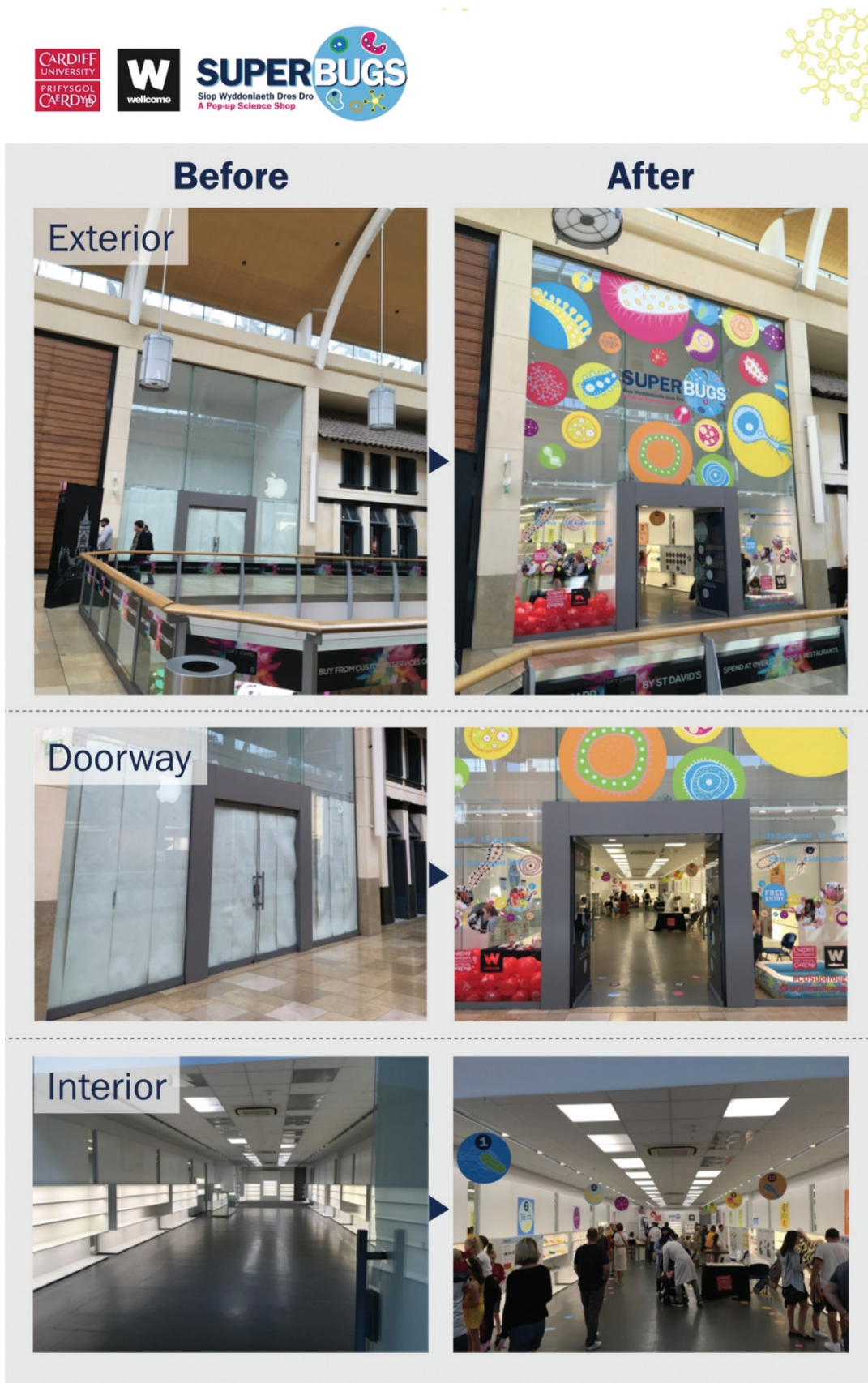
- Arts and crafts element
- Dress-up corner with photo opportunities
- Introduce a competitive element – opportunity to complete challenges and win prizes
- Materials and action lists for adults

#### Unattractive features to avoid

- Potential for long queues, which would put off casual visitors
- Avoid overly graphic images of infection/diseases



Figure 2. Transformation from empty retail unit to 'Superbugs: A Pop-up Science Shop'  
(Source: Authors, 2022)



inhabit our bodies, adding intrigue to attract further attention from the public. Acting on feedback from our focus group (see Box 1), the design was overhauled for the purpose of 'Superbugs', using brighter colours with the aim of attracting a younger audience, and enlarged to create a range of super-sized 'Superbugs'. Strategically, the 'Superbugs' unit was well placed within St David's. It was located directly opposite the Apple Store, within sight of other major retail units, such as John Lewis. Additionally, we were situated around the corner from the major family-friendly food quarter of the shopping centre, and close to the access point of the centre's crazy golf site, during the summer holidays. All of this guaranteed a good level of natural footfall, ensuring that our large and colourful exterior design (Figure 2) had great visibility throughout the central concourse of St David's.

## Promotion of 'Superbugs'

It is important to note that prior to the event, our promotional activities were limited compared with other engagement activities in the university, in part to maximise the sensitivity in measuring engagement from passers-by of our public location. First, we ran a simple social media campaign promoting our e-poster. In the week leading up to the event, we ran a short promotional campaign in *Primary Times Cardiff & Vale* (<https://www.primarytimes.co.uk/cardiff/>), which involved advertising the event on social media and featuring 'Superbugs' in their 'What's On' pages. An email with an e-poster advertising the event was sent to all secondary and primary schools in Wales that were already in the engagement network of the School of Medicine through our 'Science in Health' events (Cardiff University School of Medicine, n.d.). During the first few days of the event, we carried out a limited leaflet drop of one thousand flyers at tourist and visitor hotspots around the city centre, including the library, museum and information desks.

## Scientific content

The Wellcome Trust (n.d.) *Reframing Resistance* report identified the importance of approaching AMR engagement in terms of how the way an issue is 'framed' – explained and presented through specific themes and angles – can influence how it is received by an audience. Informed by a multi-phase international research project, the report outlined a 'Framing Toolkit' identifying five principles for how AMR communication and outreach should be framed: (1) frame antimicrobial resistance as undermining modern medicine; (2) explain the fundamentals succinctly; (3) emphasise that this is a universal issue – it affects everyone, including you; (4) focus on the here and now; and (5) encourage immediate action. Coordinating these frames is likely to create communication that informs, motivates and persuades.

Roope et al. (2017) have demonstrated that a message of warning on the dangers of AMR was not successful in imparting a positive influence on either the public's attitude or practice in requesting unnecessary antibiotics, particularly in cohorts with low AMR awareness. Subsequent studies revealed that combining a strong fear warning with messages of empowerment for the stakeholders did, in fact, induce a positive response in a way that 'fear-only' and 'mild-fear-plus-empowerment' messages did not (Roope et al., 2020), resulting in patients being less likely to request antibiotics. The paper concluded that 'fear could be effective in public campaigns to reduce inappropriate antibiotic use but should be combined with messages empowering patients to self-manage symptoms effectively without antibiotics' (Roope et al., 2020). These findings certainly reflect similar such conclusions from public campaigns in other areas of health-care science.

We adopted such approaches when designing the content of the 'Superbugs' shop. We did not shy away from showing the symptoms and wider burdens of particular examples of infections, and the broader implications of AMR in the failure to treat these, which highlighted the current impact of drug-resistant infections, rather than projections or apocalyptic frames. However, alongside this was a message of positivity, detailing the many strategies by which we are fighting the issue of AMR, illustrated using multiple examples relevant to the audiences we were engaging. These included improvements to sanitation, agricultural use, surveillance, and the development of new drugs and vaccines, demonstrating how drug-resistant infections are a cross-cutting threat across all of medicine (beyond specific disease



areas), which undermine treatments on which we have come to rely. Further to this, we provided many sources of information about how stakeholders can play an important role in the fight, framing the issue as solvable, and providing specific calls to action, for example, that it is important to complete a full course of antibiotics when they are prescribed. In order to be as inclusive as possible, and in line both with the recommendations of the Welsh Government and the specifications of the original grant remit, all activities and information sheets were available bilingually in English and Welsh.

It was decided very early in the project to avoid making any assumptions about prior knowledge of the topic of AMR among the stakeholders, so as not to compromise our overall message. As such, it was decided to begin the narrative of the event on the basics of microbiology, the bacteria that live in, on and around us, before introducing the ideas of infection and treatment. At the forefront of our messaging was an emphasis on AMR as a universal issue, and that anyone could be affected. The project included an explanation of the part that human activity is playing in accelerating the issue. In this way, we hoped to engage the public in AMR from an informed position on their part. Two early career researchers working in the area of AMR were recruited to work alongside the core team's scientists to form a 'scientific content' team, to develop the narrative and details of the exhibition. A description of the stations available to the stakeholders can be seen in Figure 3. Title cards on the wall and hanging from the ceiling, alongside bacterial 'footprints', indicated the suggested route around the shop, but visitors were welcome to engage on their own terms.

## Project output

### Evaluation strategy

It is widely acknowledged that rigorous and impactful evaluation of public engagement events is challenging, particularly in multifaceted projects such as 'Superbugs'. We wished not only to evaluate our ability to improve the awareness of AMR in our visitors, but also to evaluate the forum of a pop-up science shop itself as an effective public engagement delivery strategy. To achieve this, we took a multidimensional approach to evaluation, collecting data in a variety of ways to provide as detailed a data set as possible, with reference to a common evaluation framework proposed by Reed et al. (2018) (see Table 2). This framework provided a philosophical backdrop for our evaluation strategy, and we will adopt several of the principles outlined within it in future iterations of our 'Superbugs' events. As part of our evaluation strategy, the team reviewed the possible outcomes and impacts of the novel project approach through development of a logic model (Table 1), which explored the inputs, outputs, activities, outcomes and impacts of the project. This was adapted on numerous occasions to ensure feasibility and reach.

### Qualitative output

Over the course of two weeks, we welcomed a total of 6,566 visitors to the 'Superbugs' shop. This vastly exceeded our expectations of between 1,000 and 1,500 per week (modelled on previous pop-up shop examples), and we had to adapt quickly to meet the overwhelming demand for the consumable elements of the shop (arts and crafts, culture plates for Station 4, questionnaires and sticker cards). Typically, visitors stayed at the event for between ten minutes and one hour.

Questionnaires were completed by 10 per cent ( $n=656$ ) of visiting parties, which is particularly impressive when taking into account that a significant number of our stakeholders were family groups with, in many cases, one parent/child completing a questionnaire on behalf of the whole family. Returning a completed questionnaire to the organisers was incentivised by entry into a twice-daily prize draw to win a bag of 'Superbugs'-branded prizes. Station 5 ('Create your own microbes') produced over 500 pieces of artwork, many of which adorned the walls of the shop throughout the event and featured prominently in our social media campaign. Over 300 items of activities and reading material were taken from Station 5. At Station 4 ('Grow your own microbes'), we generated 2,169 swab plates, with the subsequent social media posts garnering over 2,500 views.

Figure 3. An outline of the stations of 'Superbugs: A Pop-up Science Shop' (Source: Authors, 2022)



**Table 2. Word clouds summarising feedback received by visitors (Source: Authors, 2022)**

<b>(A) What have you learnt?</b> Summary of the feedback from 116 visitors on the bacterial thought tree				
Viruses and bacteria can be spread by rats	Bacteria can share DNA	Antibiotics do not kill viruses	Infections become resistant to many antibiotics	Bacteria grow on your hands
Bacteria can be good and bad	There are bacteria everywhere	Always wash your hands	I have learnt that different bacteria can be dangerous	I learnt about antibiotic resistance
Bacteria can duplicate and spread	Science is fun	What bacteria look like	Antibiotics kill bacteria	It takes years to find new antibiotics
<b>(B) What did you like most about the 'Superbugs: A Pop-up Science Shop' event? What did you find most useful/interesting?</b> Selection from 202 responses to this question on the 'Superbugs' questionnaire				
The activities were brilliant and informative. They liked the coconut shy game	'Grow your own microbes' was good, and my sons loved the killing the infection game.	'Grow your own bugs' station, UV station to see bugs and the microscopes		
The whole thing was well presented, informative and fun	Interactive games and the colouring/activity table	All of the things, this should be everywhere. Great educational experience.		
The staff were good with the kids. Very engaging	The resistance stall – a clever way to teach about antibiotic resistance	The activities were very engaging for young age groups		
<b>(C) What ways could we improve 'Superbugs: A Pop-up Science Shop' in future?</b> Summary of 53 responses to this question on the 'Superbugs' questionnaire				
More often, and if it can be done in schools	Messy play	Make it a permanent fixture	An app that could be downloaded to walk around with	
Some language suitable for 5 year olds	A live demonstration	Perhaps better advertise	Make it bigger, more to the street	

Owing much to these swab photographs, our social media presence gained significant interest (Figure 4). The Systems Immunity Research Institute Facebook page, where we posted the swab photographs from Station 4 (<https://www.facebook.com/SystemsImmunity>), saw a 233 per cent increase in traffic over the course of the event, with 6,000–9,000 new weekly organic impressions and 2,000 direct hits on the official 'Superbugs' website at Cardiff University ([www.cardiff.ac.uk/superbugs](http://www.cardiff.ac.uk/superbugs)). On Twitter, we saw over 140,000 impressions across the three main Twitter accounts promoting the event: @JTyrrell\_Micro, @CUSystemsImmu and @CUMedicEngage. As the official Twitter page for the School of Medicine, @CUMedicEngage saw a 20 per cent increase in followers over the course of the 'Superbugs' event. The Twitter hashtag #CUSuperbugs evidences the positive experiences of individuals accessing the AMR public engagement with research interactive science shop, and provides a visual and storytelling narrative of the public experience.

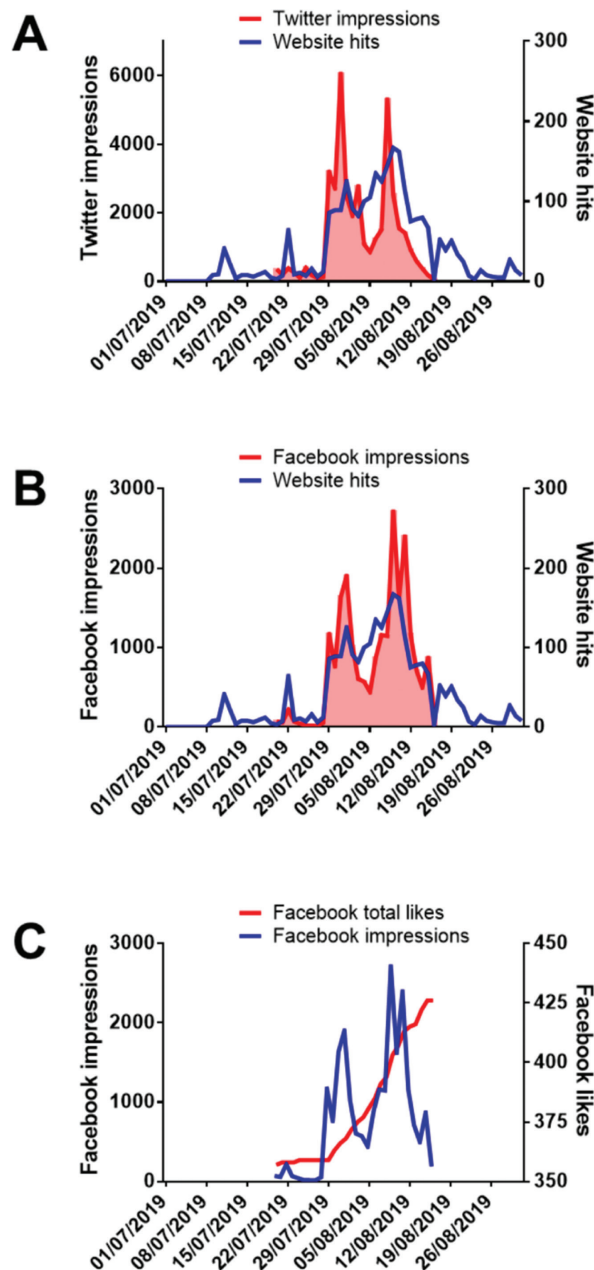
At Station 1, each young visitor was given a sticker card, corresponding to six activities throughout the shop (at Stations 4, 5, 6, 8, 9 and 11; see Figure 3). Once all six stickers were collected, they were awarded the title of 'Antibiotic Resistance Champion', their choice of a 'Superbugs'-branded prize (pen, bookmark, badge or balloon) and a certificate with handy tips about how the new champion could help scientists and society at large in the fight against AMR. We created 1,626 Antibiotic Resistance Champions, representing schools in Wales and further afield. This adopted the theories underlying the 'behavioural pledge' approaches that were previously successful in handing a level of responsibility to stakeholders to facilitate positive actions and to reinforce their aims and objectives (Kesten et al., 2017; Little et al., 2015; Eley et al., 2018).

Figure 4. Social media activity and web traffic before, during and after the 'Superbugs' event (Source: Authors, 2022)

(A) Time course of direct hits on the 'Superbugs' website ([www.cardiff.ac.uk/superbugs/](http://www.cardiff.ac.uk/superbugs/)) and impressions on the @CUSystemsImmu Twitter account

(B) Time course of direct hits on the 'Superbugs' website and impressions on the SystemsImmunity Facebook account (<https://www.facebook.com/SystemsImmunity>)

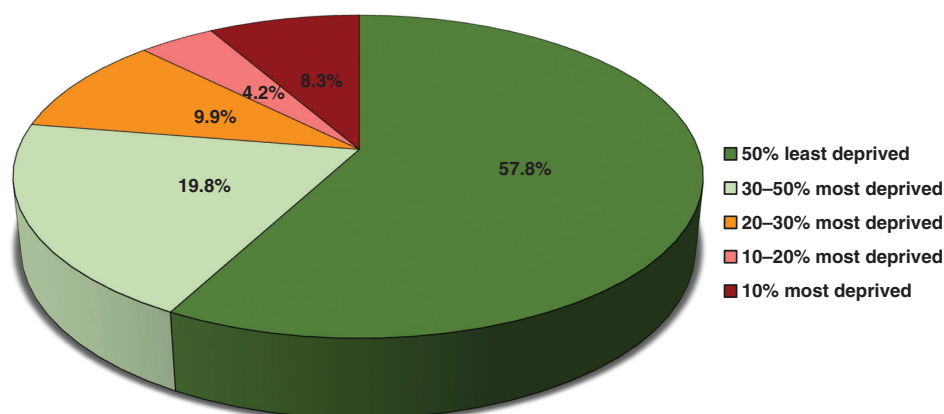
(C) Time course of impressions on the SystemsImmunity Facebook account and development of Facebook followers



Schools (n=193) which child participants attended were mapped by the Welsh Index of Multiple Deprivation (WIMD) of their geographical location. All were categorised into one of the following rankings: 10 per cent most deprived (ranked 1–191); 10–20 per cent most deprived (192–382); 20–30 per cent most deprived (383–573); 30–50 per cent most deprived (574–955); and the 50 per cent least deprived



**Figure 5. School locations of child stakeholders mapped by Welsh Index of Multiple Deprivation (WIMD) (Source: Authors, 2022)**



(956–1,909). Percentage distribution found within each of these categories is shown in Figure 5. Schools not located in Wales are not included in the analysis.

## External outputs

The event received a notable amount of local media attention. We were involved in a fun feature on the *Josh & Kally* radio show for Capital FM South Wales. The presenters were invited to swab themselves live on air, and we returned the next day to deliver the results as to who grew the most microbes. This was a unique way to engage a young demographic with the topic of bacteria, and to inform wider groups about the ongoing 'Superbugs' event. The local television station Cardiff TV spent over an hour in the shop filming visitors engaging with our activities, and interviewing members of the 'Superbugs' team. Two videos were produced and shown repeatedly across the local area for the remainder of the event, and they can be found on the events homepage (<https://www.cardiff.ac.uk/superbugs>).

We were also able to raise interest and attention from high-profile stakeholders, including Kirsty Williams AM (Welsh Minister for Education and Skills), and a visit from the local Member of Parliament for Cardiff Central, Jo Stevens (then Shadow Secretary of State for Digital, Culture, Media and Sport), in addition to tweets and retweets by several Welsh journalists. Jo Stevens took part in various 'Superbugs' activities, including swabbing her mobile phone to grow any contaminating microbes, and she wrote a blog post about her experience.

More recently, 'Superbugs' was accepted as an entry to the National Co-ordinating Centre for Public Engagement (NCCPE) 'Engage 2020' conference that took place online between 30 November and 4 December 2020. Our video submission to the event can be found on YouTube as part of NCCPE's 'Examples of practice' playlist (NCCPE, 2020).

## Impact of project

### Impact on public engagement delivery strategy

A primary aim of 'Superbugs' was to evaluate this form of public engagement, a novel proposal both for the School of Medicine, and for Cardiff University as a whole. We hypothesised that this mode of delivery would be successful in reaching a wide demographic, beyond the limited cohorts who would typically seek out opportunities to engage in scientific research. We were able to collect school locations for many of our newly crowned Antibiotic Resistance Champions (Figure 5), accounting for 1,626 children across at least two hundred schools. We cross-referenced this data with the WIMD interactive tool (Welsh



Government, 2019), the 'official measure of relative deprivation for small areas in Wales'. The WIMD considers eight distinct domains: income, employment, health, education, access to services, community safety, physical environment and housing. Rather than focus on one domain in particular, we considered 'overall deprivation' in our analysis. Of the schools referenced in Figure 5, 43 schools were found to be within the 30 per cent most deprived areas in Wales, and 16 of these were found to be located within the 10 per cent most deprived areas in Wales.

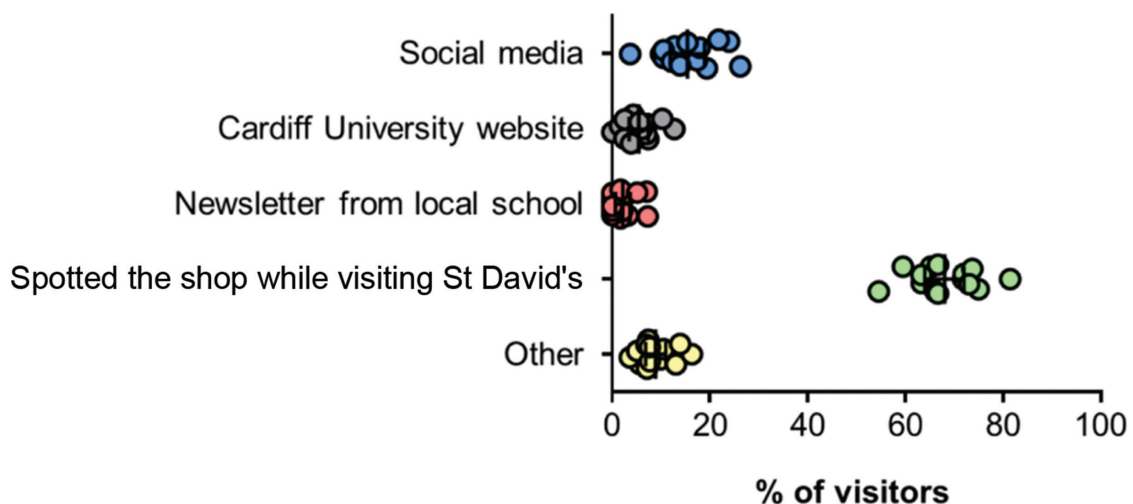
Questionnaire data showed that 67.3 per cent of entries were impromptu visits with no prior knowledge of the event before spotting it on the concourse of St David's (Figure 6). This was significantly higher than those visitors indicating any awareness due to aspects of our promotional campaign, including advertisements in the *Primary Times* magazine, website and social media. While confirming our hypothesis, it was also a triumph for the imaginative and imposing exterior designed by our team and informed by our focus group. This also suggests that for future engagement events located in public spaces, significant resources may be better focused on providing the most attractive possible experience for visitors, alongside a less broad, more targeted promotional campaign in keeping with what was delivered for 'Superbugs'.

The importance of our focus group in shaping the nature of the content and the overall design theme for 'Superbugs', and the impact this had on the success of the event, illustrates the potential in utilising focus groups, public involvement and co-production in shaping such projects. We hope this leads to developing a culture of increased efforts for co-production and public involvement across engagement activities, to the benefit of the scientific community and public alike.

Further confidence in our strategy was corroborated in the data collected through our questionnaires (Table 3): 95 per cent and 91.9 per cent of visitors, respectively, *agreed/strongly agreed* that the event was fun, engaging and informative, and that we had pitched the intellectual level appropriately. We are very proud to say that over 94 per cent of visitors indicated that they not only rated 'Superbugs' as *very good* or *excellent*, but, perhaps even more significantly, they would also recommend 'Superbugs' to others.

Following a visit, Professor Kim Graham, Pro-Vice Chancellor for Research, Innovation and Enterprise at Cardiff University, and Professor Gary Baxter, Pro-Vice Chancellor for the College of Biomedical and Life Sciences at Cardiff University, took to social media with positive tweets of their experience, and encouraged others to visit 'Superbugs'. This endorsement from senior leaders at the university highlighted the high-level profile of the 'Superbugs' project, and the significance of public engagement with research for higher

**Figure 6. 'Where did you hear about "Superbugs: A Pop-up Science Shop"?' (Questionnaire Q9): (A) Social media (Facebook, Twitter), including *Primary Times*; (B) Cardiff University website; (C) Newsletter from local school; (D) Spotted the shop while visiting St David's; (E) Other; data collected from questionnaires over 14 consecutive days (n=656); individual data points show daily answers; error bars show mean values and 95 per cent confidence intervals (Source: Authors, 2022)**



**Table 3. Percentage of stakeholders that selected agree/strongly agree with statements about 'Superbugs' in data collected from questionnaires (n=656) (Source: Authors, 2022)**

	Strongly disagree (%)	Disagree (%)	Neutral (%)	Agree (%)	Strongly agree (%)
[Q1] "'Superbugs' was a fun, engaging, informative event'	3.7	0.2	1.1	27.9	66.7
[Q2] 'We have a better understanding of the world of microbes because of "Superbugs"'	3.8	0.3	3.1	38.4	54.3
[Q3] 'We have a better understanding of antibiotics and how they work'	3.9	0.3	3.3	37.5	55.0
[Q4] 'We have a better understanding of antibiotic resistance'	4.0	0.6	3.7	35.4	56.3
[Q5] 'We are more likely to take a full course of antibiotics'	3.9	0.8	4.5	33.4	57.4
[Q6] 'We are likely to tell others about what we have learnt'	4.1	0.6	4.1	33.5	57.8
[Q7] 'The intellectual level of content was pitched appropriately for a family audience'	3.9	0.6	3.6	33.6	58.2
[Q8] 'We would recommend "Superbugs: A Pop-up Science Shop"'	4.0	0.2	1.4	19	75.4

education institutions. Future conversations were invited from senior leaders to explore this model of engagement, its potential for societal change and how such activities can be sustained in the longer term.

### Impact on AMR awareness for stakeholders

We may accept the hypothesis that our pop-up shop was an effective way of imparting positive impact on AMR awareness to the public audience with whom we engaged. Our benchmarking exercise, where visitors were asked to indicate their understanding of three simple but targeted questions to gauge their baseline knowledge, before repeating the exercise on leaving, provides strong supportive evidence for this. The three questions asked are shown in Figure 7. Across all three questions, there was a significant increase in the percentage of correct answers after engaging with the 'Superbugs' activities. The largest increase was seen in the most fundamental question, 'Antibiotics are used to kill ...'. The rate of visitors correctly answering 'bacteria' increased from 53.1 per cent to 80.7 per cent. This illustrates not only the positive impact we had on our stakeholders, but also the pertinence of engagement on such fundamental topics.

Table 3 further illustrates that 'Superbugs' improved understanding of the world of microbes, antibiotics (and how they work) and antibiotic resistance in 92.7 per cent, 92.5 per cent and 91.7 per cent of cases, respectively. Perhaps more significantly, our evidence supports a progressive influence on future behaviour and attitudes towards antibiotic stewardship, with 90.8 per cent of participants now more likely to complete a full course of antibiotics. Improved antibiotic stewardship has significant and far-reaching implications for our ability to control AMR pathogens (File et al., 2014).

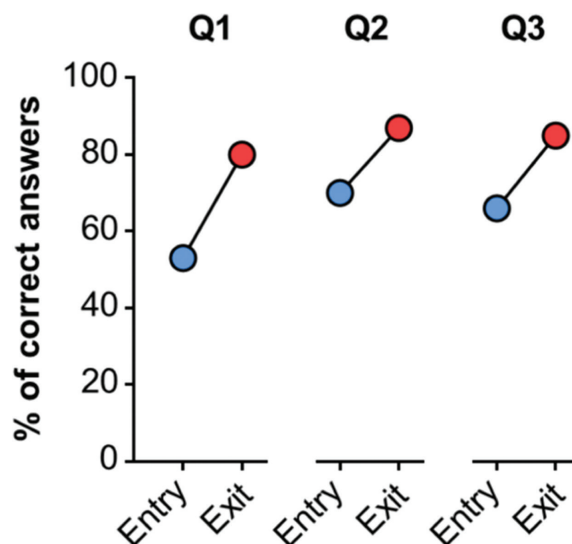
Secondary to this, we may infer far-reaching legacy impact of our event: 1,626 young people left not only with the title 'Antibiotic Resistance Champion', but also with their certificate detailing tips about how they can further their knowledge and spread the word long after the doors of 'Superbugs' had closed. As a testimony to the success of this approach, 91.3 per cent of visitors completing the questionnaire stated that they would pass on what they had learnt at the event (Table 3).

Figure 7. Comparison of correct answers to benchmarking questions by stakeholders on entry and exit to 'Superbugs' (questions are listed with correct answers underlined) (Source: Authors, 2022)

[Q1] 'Antibiotics are used to kill...' (A) Viruses, (B) Bacteria, (C) Fungi, (D) All of the above.

[Q2] 'When taking antibiotics you should...' (A) stop when you feel better, (B) Take all the antibiotics as instructed by your doctor, (C) Save some for next time you feel unwell, (D) Share them with your friends.

[Q3] 'Antibiotic resistance is a problem for...' (A) only people taking antibiotics, (B) Everyone, (C) The elderly and sick, (D) Those who travel to exotic countries.



### Impact for the institute and staff

'Superbugs' provided a valuable opportunity for professional development for all involved. For several of the core team, it was their first experience of independently securing grant funding, and the organisational and administrative responsibilities that come with it.

Logistically, 'Superbugs' was a mammoth undertaking, requiring staff to give up their own time to take part. In total, 33 volunteers helped deliver aspects of the event, involving 5 or 6 individuals being present at the shop and facilitating the activities at any one time. Station 4 ('Grow your own microbes') in particular required extra-curricular assistance in the incubation, sorting and photography of all the swab plates generated, and the subsequent uploading of the anonymised photographs to a bespoke Facebook album. Volunteers were at various stages of their careers, and from backgrounds across the academic spectrum, from professional staff, research associates and senior academics, to students ranging from undergraduates to PhD students, and, for many, 'Superbugs' represented their first experience of public engagement. On their first day of volunteering, all were fully briefed on the content of the shop, and on the concept and messages behind each activity. Each day, we attempted to provide a mixture of inexperienced 'engagers' and more senior staff, in order to breed a supportive environment where communication skills could be developed and enhanced.

As described, we saw an incredible response to our Station 4 'Grow your own microbes' activity, with 2,169 swab plates collected. The enthusiasm with which visitors engaged with this suggests a potentially rich resource that could be employed for research purposes, and could provide a unique insight into the social and environmental spread of target microorganisms, and the anthropogenic factors driving this dissemination.

'Superbugs' instigated a significant influx of activity and attention to the social media and web pages of the School of Medicine public engagement team. Across the academic year, the School of Medicine delivers a wide portfolio of engagement activities for students at primary and secondary schools, and the

wider public, including a free-access public lecture series, the Wales-wide Life Sciences Challenge quiz, and the 'Science in Health Live!' event and laboratory work experience scheme that both provide unique opportunities for Year 12 school students to visit the working environment of the University Hospital of Wales in Cardiff (<https://www.cardiff.ac.uk/medicine/about-us/engagement>), witnessing cutting-edge technologies and research at first hand.

## Access for protected characteristics

A cornerstone of the delivery strategy of 'Superbugs' was the hope to break out from traditional cohorts of those scientifically aware, to wider and more diverse demographics, including those of age, culture and religion. Enrolling Diverse Cymru as a strategic partner provided us with an independent and judicious evaluation of how 'Superbugs' met the needs of, and appealed to, people with protected characteristics, and ways in which we could improve this even further for future activities. This was considered during the design of the shop layout, ensuring information and activities were accessible for a range of heights and abilities, and that there was adequate space to accommodate mobility aids. Highlighted was the need to more apparently cater for those with sensory, learning and cognitive impairments, primarily in some of the language used in areas of the shop, and the prominence of instructions for our activities. In addition, we are committed to applying decolonisation of all information provided in future 'Superbugs' events, to reflect a more accurate, diverse and global view of the topic area.

## Discussion

To our knowledge, this is the first pop-up science shop designed to increase the awareness and knowledge of the general public of the microbial world, infection biology and the increasing threat of antibiotic resistance to global public health. A recent review article by Redfern et al. (2020), providing a comprehensive overview of outreach and engagement activities aimed at raising awareness of AMR, further corroborates the novelty of our project. Attracting 6,566 visitors in a two-week period during the school summer holidays indicates a strong thirst for such engagement in research by members of the public.

Based on the qualitative and quantitative data collected, the anecdotal feedback received, and personal communication from senior academic colleagues, we are confident in concluding that 'Superbugs' made positive strides in raising awareness of the AMR crisis and educating the public about the part they need to play in the fight against this global issue. The data presented here indicate that we have met the aims we set, and achieved the outputs we had strived for at the beginning of the project. We created an environment of two-way dialogue with wide and varied public demographics, imparting a positive change in the awareness of microbiology and AMR. Concurrently, 'Superbugs' has illustrated the efficacy of public space-based engagement in doing so.

## Limitations and future improvements

'Superbugs' was delivered in one city-centre location in Cardiff, the capital of Wales. It is the ambition of the project team that future deliveries of 'Superbugs' events act to widen the accessibility to include other cities and towns across Wales, particularly those outside southern hubs. This would enable us to compare the impact of 'Superbugs' across different geographical and socio-economic areas, of more diverse stakeholder demographics, and provide deeper data sets with which to evaluate the efficacy of our engagement model. Immediate barriers to this exist, however, primarily in the acquisition of unique funding sources, and the recruitment of adequate volunteer numbers.

As has already been indicated, this project was built upon the time and hard work of the core project team, and the willingness of an army of volunteers to give up their own time to participate. In the lead-up to the event itself, we began a recruitment drive through the communication networks of

the School of Medicine, and, more widely, the College of Biomedical Life Sciences. Regrettably, uptake outside the research groups of the involved academics was limited, and at certain times volunteer numbers during the event were limited to the point of threatening to compromise the experience for our visitors. Notwithstanding this, 'Superbugs' presented a valuable, but missed, opportunity to develop communication and outreach skills, and to gain insight into how public engagement activity with research may support the development of pathway to impact statements. It should be noted that one potential contributor to this was the timing of the event during the summer holidays, perhaps suggesting the importance of budgeting of staff time in the organisation of large-scale engagement and outreach events.

This also highlights an intrinsic issue within academic culture and attitudes towards public engagement activities. Historically, public engagement may have been seen simply as a way in which to educate the 'scientifically illiterate'. As such, the discipline of public engagement has been underserved in time, attention, funding and willingness to participate (as evidenced here) by academic institutions and the staff therein, perhaps being seen as nothing more than a pleasant aside to the primary roles of researchers. This is exacerbated by an environment that prioritises quantifiable publications and grant funding in determining career prospects and progression.

The introduction of 'impact' (encompassing public engagement) as an element of assessment for REF 2014 is perhaps a clear signal of a slow paradigm shift in this regard, and the value with which public engagement and impact is perceived (Copley, 2018). Increasingly, public engagement is seen as a tool to raise university profiles, influence policymakers (both directly and indirectly) and further quantify research impact. In this context, we are proud that our efforts have been recognised with the Cardiff University School of Medicine's STAR Award 2020 for 'Outstanding Contribution to Engagement Activities', awarded to the team lead, Dr Jonathan Tyrrell, in June 2021. More standardised frameworks for the design, implementation and evaluation of public engagement activities are required to advance the integrity and rigour of this capacious discipline, and there is a growing literature to achieve this (Mahony and Stephansen, 2017). Furthermore, as the demand for public engagement with research activities continues to increase from funders, concern around recognition, value and support among employers requires further exploration.

## Final remarks

Currently, we as a society are facing the challenges of the COVID-19 pandemic. It would be remiss, however, to overlook the more silent pandemic of AMR, which has been with us for decades, and which continues to have severe impacts, both economically and on public health. Increasingly, a consensus view is emerging that the COVID-19 pandemic actually threatens a further exacerbation of the antibiotic resistance crisis worldwide (Miranda et al., 2020; Murray, 2020). An alternative view holds that the reduction of international travel may inhibit the global dissemination of AMR pathogens, and that scientific communication regarding this viral pandemic may lead to improved awareness about the appropriate use of antibiotics (Murray, 2020). It is clear that there will be a post-COVID-19 impact on AMR, even if the true nature and parameters of this are not yet known (Monnet and Harbarth, 2020). Either way, it is evidently pertinent to continue effective and impactful engagement of the public on the topic of infectious disease.

'Superbugs' is now an inter-institutional collaboration between academic staff of the University of Bristol and Cardiff University, which will present unique opportunities for the future of the project in terms of size and scope, and applications for future funding. As with all things, 'Superbugs' has had to adapt to a new COVID-19 world where large-scale, in-person engagement events are simply not possible, at present and for the foreseeable future. In August 2020, we therefore successfully secured grant funding through the ISSF3 Public Engagement Co-production Award to co-produce a permanent online/digital website presence for 'Superbugs', and we are currently recruiting stakeholders from across the education sector, while designing our co-production and evaluation strategies. Immersive and interactive events in public spaces will continue to be at the heart of what we deliver with 'Superbugs', and we were pleased that just before the arrival of COVID-19 in Wales, a first successful redelivery of select 'Superbugs' activities was run as part of Cardiff Science Festival in February 2020.



Increasing public awareness around AMR and antibiotic use now forms a cornerstone of the UK government's 20-year strategy in managing and controlling the issue (GOV.UK, 2019). Redfern et al. (2020) comprehensively outline several activities, representing a diverse range of approaches, which have been implemented to this end, and in doing so highlight a pertinent point. Simply, in undertaking a systematic review of AMR-related engagement activities, an intrinsic limitation was the relative paucity of publications based on such activities. Indeed, there is a similar problem for microbial literacy within the public and education sectors also (Timmis et al., 2019), and this is further reflected in the Wellcome Trust's (n.d.) *Reframing Resistance* report. We hope that this account of 'Superbugs: A Pop-up Science Shop' will contribute to a growing body of work laying the foundations to address such a problem, and in doing so will leave a lasting impact on addressing public awareness of the AMR threat, and the best practices to achieve this aspiration.

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## Declarations and conflicts of interest

### Consent for publication statement

The authors declare that participants' informed consent to publication of findings – including photos, videos and any personal or identifiable information – was secured prior to publication.

### Conflicts of interest statement

The authors declare no conflicts of interest with this work. All efforts to sufficiently anonymise the authors during peer review of this article have been made. The authors declare no further conflicts with this article.

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