

1 **‘Superbugs: A Pop-up Science Shop’: Increasing public**
2 **awareness and knowledge of antimicrobial resistance by taking**
3 **science to the city**

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19
20 **Abstract**

21 ‘Superbugs: A Pop-up Science Shop’ was a public engagement event in the school summer
22 holidays of 2019, organised by members of Cardiff University’s School of Medicine. We
23 transformed an empty retail unit in the centre of Wales’ largest shopping centre into an
24 interactive and immersive microbiology experience. We aimed to facilitate opportunities for
25 two-way dialogue to impart positive impact on the awareness of antibiotic resistance, whilst
26 concurrently evaluating the efficacy of an engagement strategy focused on the utilisation of
27 public spaces to attract public demographics diverse to those who would normally engage with
28 STEM outreach.

29 Over the course of 14 days, we welcomed 6,566 visitors, with 67% attending as part of
30 the natural footfall of the shopping centre. We created 1,625 young Antibiotic Resistance
31 Champions, located in over 200 schools. Through a multi-lateral evaluation strategy, we were
32 able to collect quantitative and qualitative feedback on the success of our delivery model, and
33 the impact on our stakeholders. Herein, we will discuss the evolution of ‘Superbugs’ from

34 concept, planning and design, to the logistics of delivering an engagement event of this scale.
35 We will focus in particular on the learning outcomes of the project, and how this will shape the
36 future of our ‘Superbugs’ project, and engagement events beyond.

37

38 **Key Words**

39 Antimicrobial resistance, antibiotic stewardship, education, public engagement with research,
40 public spaces, public awareness, science engagement, STEM

41

42 **Key Messages**

43 (1) Creating a multi-disciplinary core team is essential to the success of large-scale engagement
44 events as well as the support and development of large numbers of colleagues/volunteers

45 (2) Utilising themes of exhibition and gameplay alongside strong fear-empowerment messages
46 is an impactful way to confer positive influence and behaviour around antimicrobial resistance
47 (AMR) and the use of antibiotics

48 (3) ‘Pop-up shop’ is an effective mode of delivery to capture diverse public demographics far
49 beyond those who would traditionally engage with scientific outreach and science engagement.

50

51 **1. Introduction**

52 Antimicrobial resistance (AMR) is among the most significant threats to global public health,
53 food security, and development (<https://www.who.int/news-room/fact-sheets/detail/antibiotic-resistance>). Infections resistant to multiple classes of antibiotics compromise patient treatment
54 and carry significant economic burden. The spread of such infections is exacerbated by
55 socioeconomic factors including, but not limited to, the inappropriate use of antibiotics at a
56 local, national and international level. Given the everyday implication to public health, social
57 education and participation is paramount to the success of strategies to control the concerning
58 rise of AMR worldwide. Society has a pivotal role to play through improved antibiotic
59 stewardship, improvement and maintenance of good hygiene, vaccination and the election and
60 accountability of policy makers. Management of major AMR pathogens such as methicillin-
61 resistant *Staphylococcus aureus* (MRSA) and *Clostridium difficile* has shown that public-
62 focused campaigns around infection control and antibiotic stewardship can indeed result in
63 reduction of infection rates (Ashiru-Oredope *et al.*, 2012; Duerden *et al.*, 2015). However,
64 without adequate insight and basic understanding of infection control and antibiotic resistance
65 on behalf of society, we cannot hope for success in programmes and initiatives aimed at
66 combatting the current crisis. The WHO Global Action Plan on Antimicrobial Resistance
67

68 outlined Objective 1 of their strategic plan as ‘Improve awareness and understanding of
69 antimicrobial resistance through effective education and training’ (WHO, 2015a), testimony to
70 the importance of public participation and understanding. On 24th January 2019, the UK
71 government identified ‘Engage the public on AMR’ as one of their nine ambitions as part of
72 their 20-year vision for antimicrobial resistance
73 (<https://www.gov.uk/government/publications/uk-20-year-vision-for-antimicrobial-resistance>).
74

75 In conjunction with their action plan, the WHO published a 12-country snapshot survey,
76 the ‘Antibiotic Resistance: Multi-country Public Awareness Survey’ (WHO, 2015b). Of those
77 surveyed, 76% incorrectly identified the statement ‘Antibiotic resistance occurs when your
78 body becomes resistant to antibiotics and they no longer work as well’ as true. 64% incorrectly
79 thought that a common cold and the flu can be treated with antibiotics. Perhaps most
80 concerningly, only 18% of participants disagreed with the statement ‘There is not much people
81 like me can do to stop antibiotic resistance’. There are economic, geographical and educational
82 caveats to many of the results presented in the report, but the picture painted is a stark one.
83 Furthermore, this is not an issue limited to the lay public. Dyar *et al.*, (2018) reported that,
84 whilst 100% of healthcare students (predominately medicine, pharmacy, dentistry and
85 veterinary medicine) correctly stated that bacteria could become resistant to antibiotics, more
86 than 40% also incorrectly believed that humans and animals could also.

87 It is with active members of the AMR and infection research community, such as
88 ourselves in the ‘Superbugs’ team, where responsibility must lie; there is clearly inadequate
89 and inefficacious communication of the AMR message, the research being carried out, and the
90 role society has to play, at a time where it has never been more pertinent. Not only due to the
91 grave consequences the global AMR crisis does, and will, continue to have on mortality and
92 morbidity, and economic implications, but also to avoid the assuaging of impact of research
93 within the field. It is through these frustrations, and a desire to contribute to the readdressing
94 of the balance, that our project, ‘Superbugs: A Pop-Up Science Shop!’ was born.
95

96 **2. Aims of Manuscript**

97 ‘Superbugs: A Pop-Up Science Shop!’ was a proof-of-concept event, held in the school
98 summer holidays between 29th July and 11th August 2019, open for all 14 days in a row, 9am-
99 5pm. The event aimed to combine the philosophies of public engagement with research, school
100 outreach and science exhibition to deliver an interactive and immersive experience in a public
101 space, outside of traditional scientific and academic environments. The event utilised a vacated

102 retail unit (approximately 2400 ft² in size) in the public space of St David's (StD), the largest
103 shopping centre in Wales and one of the busiest in the whole of the UK and transformed the
104 retail unit into a professionally designed interactive research experience involving laboratory
105 activities, games, artworks, information resources and competitions surrounding the topics of
106 bacteria, antibiotics and drug-resistant infections.

107 Herein, we will explore in detail the process of conception, planning and delivery of
108 the 'Superbugs' event. Further to this, we will present much of the quantifiable output
109 generated by our stakeholders and the project team, and how this learning may be of positive
110 impact for (AMR) researchers, public engagement professionals and all organisations with a
111 public engagement agenda

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113 **3. Planning of Project**

114 ***3.1 Conception***

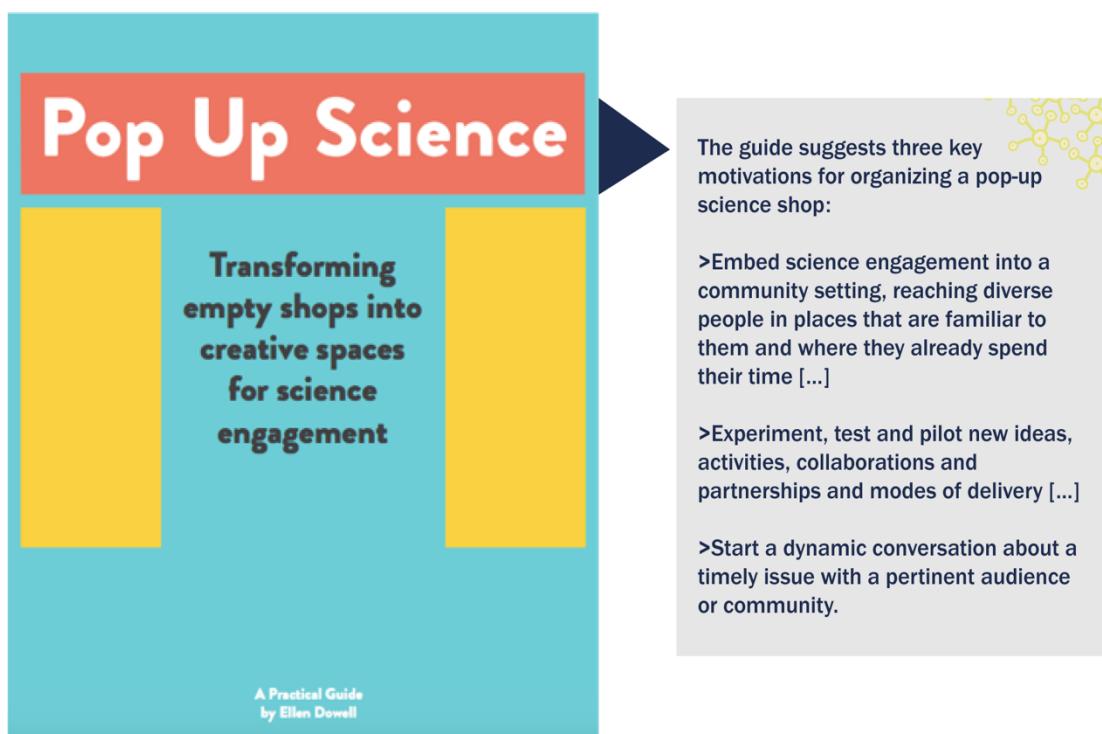
115 The concept of 'Superbugs: A pop-up Science Shop!' originated from two earlier key events.
116 The first was the organisation of 'Superbugs: The End of Modern Medicine', a public
117 engagement evening held at Techniquest, an educational science and technology museum in
118 Cardiff (https://www.cardiff.ac.uk/_data/assets/pdf_file/0007/1270852/Cardiff-University-ReMEDy-Newsletter-Edition-29_e_web.pdf). Through feedback collected from visitors, it
119 was here that the potential to deliver meaningful AMR messages through the medium of
120 exhibition, presentations, games and interactive laboratory tasks was first explored, which laid
121 the foundation for the content developed for the later pop-up science shop. The second event
122 was participation in the Cardiff University BLS (Biomedical & Life Sciences) Public
123 Engagement Development Programme, through which we were introduced to the 'Pop-Up
124 Science' report (Figure 1), and the potential of such a delivery model. Research by the British
125 Science Association and King's College London has suggested that up to 76% of UK adults
126 (defined as 16+ years olds), accounting for approximately 49 million people in total, do not
127 participate in scientific outreach, either due to lack of interest or effort to seek out such
128 opportunities. This highlights the space to further evaluate the impact of scientific engagement
129 carried out in public areas, and engagement of the 'general public'.

131 Carr *et al.*, (1992), in their text 'Public Spaces' outlined five important requirements
132 that influenced the appeal of public spaces on communities: (i) comfort, (ii) relaxation, (iii)
133 passive engagement, (iv) active engagement, and (v) discovery. It was certainly the latter two,
134 the need for mental and physical challenge (active engagement) and offering the chance to
135 evolve new ideas and interests in unfamiliar topics (discovery), that were at the core of what

136 we hoped to achieve in this project. As Carr *et al.*, so succinctly put it, ‘enable the users’ interest
137 to endure’.

138

139 **Figure 1:** Key applicable points taken from ‘Pop Up Science- A Practical guide’ published in 2017 by Ellen
140 Dowell from the National Heart & Lung Institute at Imperial College London
141 Heart & Lung Institute at Imperial College London (<https://www.imperial.ac.uk/nhli/interact/public->
142 [engagement/our-projects/pop-up-science/](https://www.imperial.ac.uk/nhli/interact/public-))



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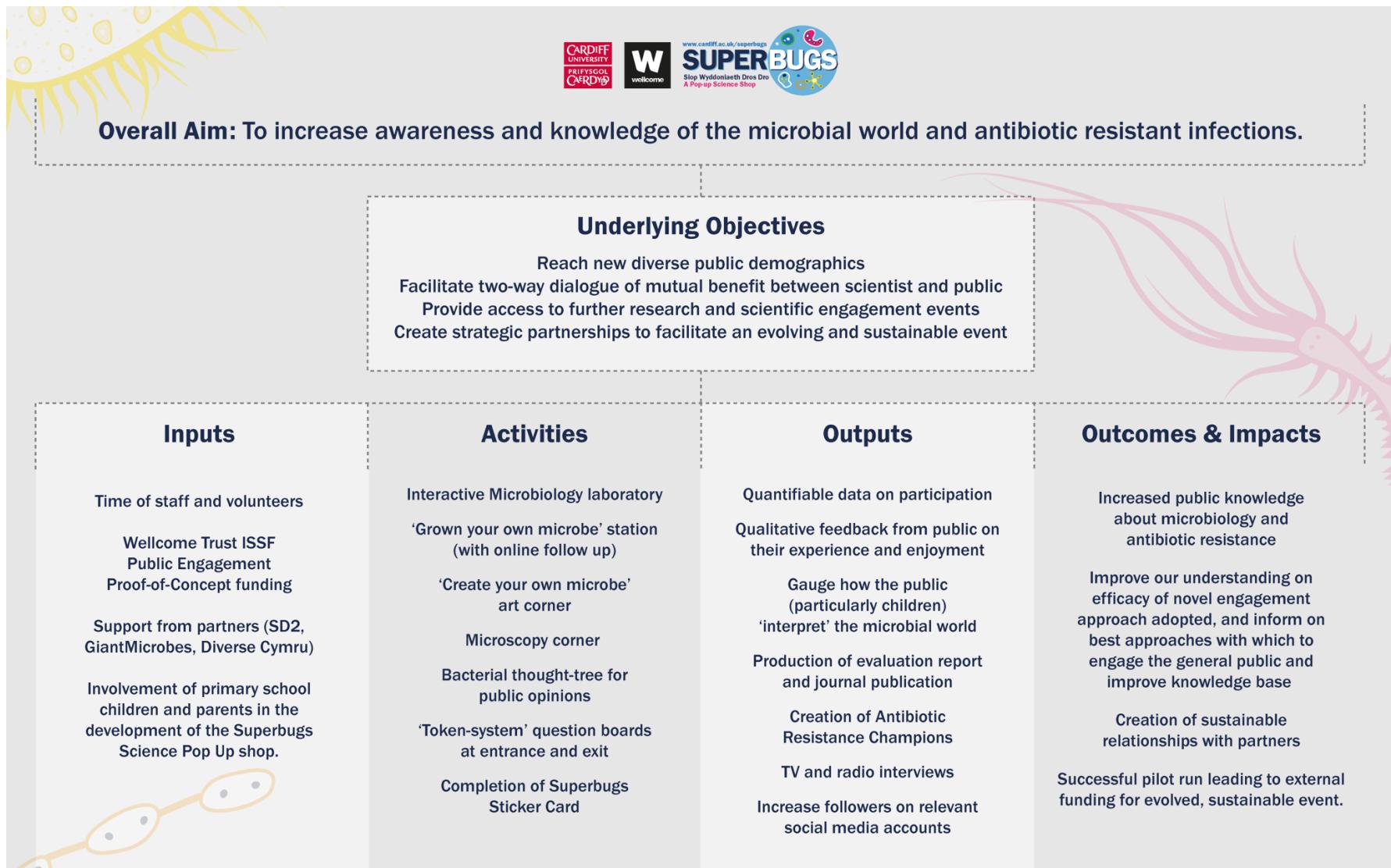
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145 3.2 Application for Funding

146 Our plans were collated into an application to the Wellcome Trust Institutional Strategic
147 Support Fund (ISSF3) on the theme of Public Engagement Proof-of-Concept funding, with the
148 proposed AMR pop-up science shop as a novel delivery model that had not been utilised before
149 at Cardiff University, nor to our knowledge more widely in the area of AMR. The overall aim
150 for the proposed project was to increase the awareness and knowledge of the general public of
151 the microbial world, infection biology and the increasing threat of antibiotic resistance to global
152 public health. Additionally, we hypothesised that by taking the event into public spaces, we
153 could evaluate the efficacy of attracting the attention of all public demographics, and not only
154 those that would traditionally attend scientific engagement events (Figure 2).

155

Figure 2: Logic Model of 'Superbugs: A Pop-Up Science Shop'



158 In order to achieve this, we defined a number of underlying objectives;

159 (i) To reach new and diverse public demographics by taking science to the people

160 (ii) To facilitate two-way dialogue of mutual benefit between scientists and the

161 public

162 (iii) To provide the public access to information about local and international AMR-

163 related research, how it impacts their lives, and further scientific-public

164 engagement opportunities

165 (iv) To create strategic relationships between Cardiff University, the public, and

166 supporting partners.

167

168 In September 2018, we were successfully awarded Public Engagement Proof of Concept

169 funding and secured contingency funding and support from the Systems Immunity Research

170 Institute at Cardiff University, a department carrying out world class research in AMR,

171 infection and immunity, where most of the funded team's scientists were based at the time.

172 Cardiff University is the leading biomedical research institution in Wales as evidenced by

173 ranking 5th overall in the UK and 8th in Clinical Medicine in the Research Excellence

174 Framework (REF) 2014 – the most recent nationwide impact evaluation assessing the research

175 at all UK higher education institutions – with its world leading basic and clinical research on

176 AMR, infection and immunity as a core strength.

177

178 **4. Delivering the Project**

179 *4.1 Multi-disciplinary team and Strategic Partners*

180 From an early stage it was identified that a multi-skilled team from various backgrounds was

181 vital to delivering the project successfully. A core team was put together from across the School

182 of Medicine including AMR research scientists, public engagement champions and

183 professionals, and a graphic designer. The benefit of this to the project was not only the wide

184 spectrum of talents and knowledge, but also the network of contacts brought to the table by

185 each core team member. In addition to this, two early career researchers (ECRs) were recruited

186 to work with us in designing the AMR-related content, of which the shop would comprise.

187 Equally as important to the success of the project were the strategic partners with whom

188 we were able to engage.

189 • St David's (StD): The largest shopping centre in Wales based in the heart of the Welsh

190 Capital, Cardiff, with a footfall of approximately 750,000 per week. Management staff

191 from StD were involved in very early discussions on the viability of providing an empty

192 unit within the centre and provided support to our funding application along those
193 grounds.

- Morgans Consult: Local signs and brand implementation specialists (<https://morgansconsult.com/>). Funding freed up by StD was invested into further professional implantation 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 we inherited from StD.
- 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.

206

207 4.2 Focus Group for Target Stakeholders

To inform the planning stages of the event, a focus group was organised for key target stakeholders: families with children of Key Stage 2 (7-11 years old) and Key Stage 3 (11-14 years old). The event was held after school hours at Rhiwbina Primary School in Cardiff and was attended by seven families recruited through an invitation forwarded onto parents by the Headteacher of the school. Children were split up into two groups and taken through a number of sample activities akin to what we hoped to deliver at the future event. Concurrently, we facilitated a discussion with the parent on various aspects of the project, before eventually coming together to gather further feedback from the children. Table 1 below summarises the key outputs taken from this focus group.

217 This approach proved to be an invaluable step in the evolution of ‘Superbugs’, not only
218 by informing the final design schemes of the shop, but by also confirming that our planned
219 activities were engaging not only to our primary target stakeholders, but also by those younger
220 and older. To quote one inquisitive four-year old after attending the focus group, ‘looking at
221 the little things in the microscope was my favourite’.

222

223 **Table 1:** Significant output from the Stakeholder Focus Group.

224 Discussion points taken from our Focus Group session that played a key role in the evolution and direction of the
225 project.

Marketing & Advertisement

- Overwhelming preference for a more colourful, less ‘corporate’ design and colour scheme, which will appeal more to families and young children
- Make obvious the flexibility in how much time visitors need to spend on the experience
- Use social media (increasingly influential for family units)
- Use of local advertising forums (Cardiff TV, Primary Times, Mummy Says, 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, would be a put off for casual visitors
- Avoid overly graphic images of infection/diseases

226

227 **5. The Content of ‘Superbugs’**

228 *5.1 General Design Concept & the Importance of Exterior Design*

229 A fundamental aim of ‘Superbugs’ was to evaluate the effectiveness and success of a pop-up
230 shop in engaging lay stakeholders of all demographics, not limited to those who would
231 traditionally seek out STEM-related events. Attracting the natural footfall in the public location
232 of the shop was thus imperative, and the investment of the project’s time and finance into the
233 exterior design of the shop reflected this. Figure 3 shows the original vacated retail unit we
234 inherited (previously a ‘Clarks’ shoe shop, with shelving and lighting still in place), and how
235 the resulting ‘Superbugs’ pop-up shop looked once opened.

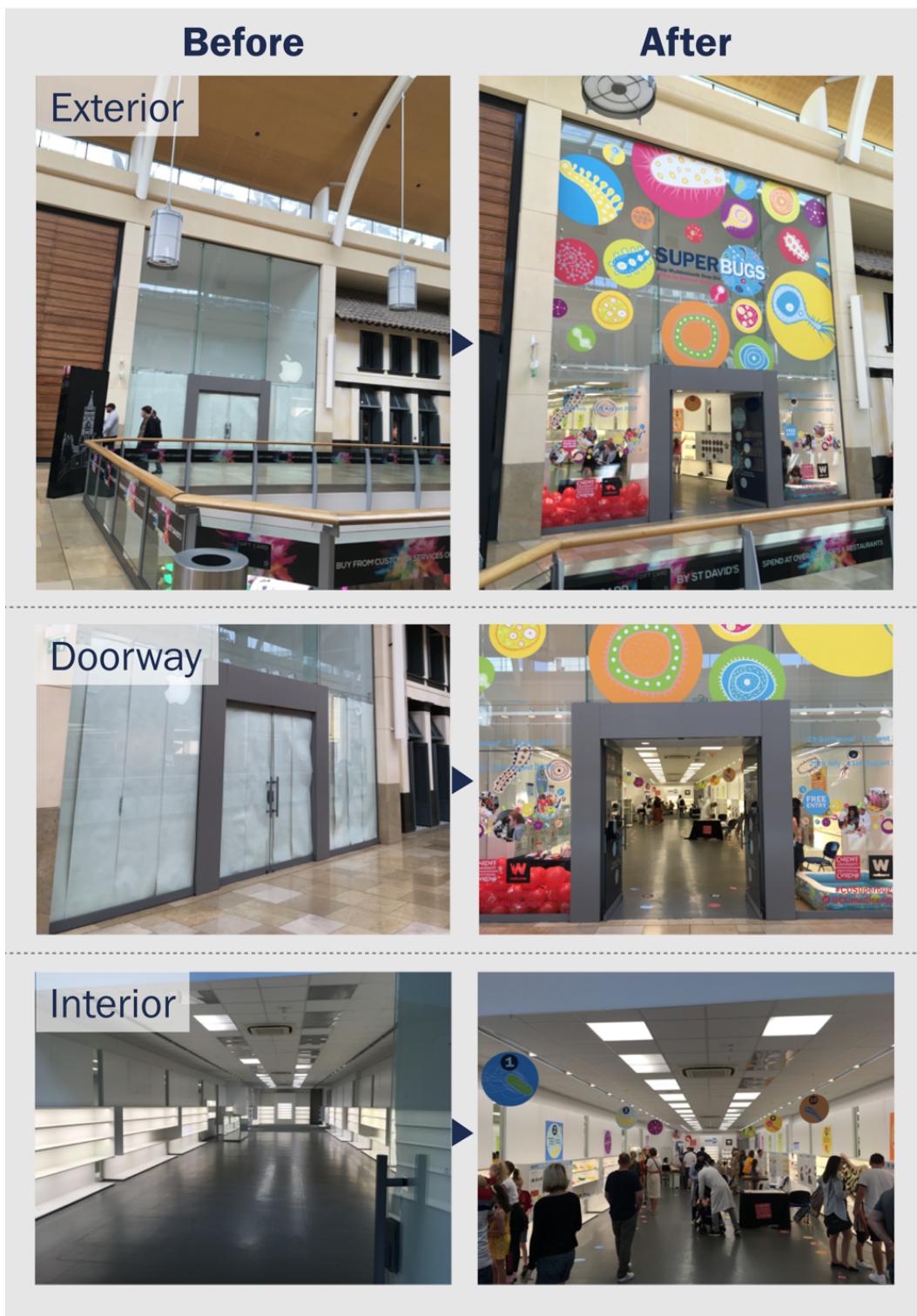
236 The origin of the ‘Superbugs’ design lies in promotional material developed for the
237 Systems Immunity Research Institute including a bus poster campaign and social media
238 (<https://www.cardiff.ac.uk/systems-immunity/about-us>). Illustrations were created to represent
239 the diversity of micro-organisms that inhabit our bodies, adding intrigue to attract further
240 attention from the public. Acting on feedback from our focus group (Table 1), the design was
241 overhauled for the purpose of ‘Superbugs’ using brighter colours than the original with the aim
242 of attracting a younger audience and enlarged to create a range of super-sized ‘Superbugs’.

243

244

245 **Figure 3:** Transformation from empty retail unit to ‘Superbugs: A Pop-Up Science Shop!’.

246 Representative photos taken before the transformation of the vacated retail in the St David’s shopping centre, and
247 during the ‘Superbugs’ event, to illustrate the changes to the interior and exterior design of the shop.



279 Strategically, the ‘Superbugs’ unit was well placed within StD. It was located directly opposite
280 the Apple Store, within sight of other major retail units such as John Lewis. Additionally, we
281 were situated around the corner from the major family friendly food-quarter of the mall, and
282 close to the access point of the centre’s family crazy golf site, during the Summer holidays. All
283 of this guaranteed a good level of natural footfall past the shop, ensuring that our large and
284 colourful exterior design (Figure 3) had great visibility throughout the central concourse of
285 StD.

286

287 *5.2 Promotion of ‘Superbugs’*

288 It is perhaps important to note that prior to the event, our promotional activities were minimal
289 by design, to maximise the sensitivity in measuring engagement from passers-by of our public
290 location. Firstly, we ran a minimal social media campaign, promoting our e-poster. In the week
291 leading up to the event we ran a short promotional campaign in Primary Times Cardiff & Vale
292 (<https://www.primarytimes.co.uk/cardiff/>) which involved advertising the event on social
293 media and featuring ‘Superbugs’ in their ‘What’s On’ pages. An email with an e-poster
294 advertising the event was sent around to secondary and primary Schools in Wales that were
295 already in the engagement network of the School of Medicine through our ‘Science in Health’
296 events (<https://www.cardiff.ac.uk/medicine/about-us/engagement/science-in-health>). In the
297 first few days of the live event, we carried out a leaflet drop at particular tourist and visitor
298 hotspots around the city centre, including the nearby library, museum, and information desks.

299

300 *5.3 Scientific Content*

301 The Wellcome Trust ‘Reframing Resistance Report’
302 (<https://wellcome.org/sites/default/files/reframing-resistance-framing-toolkit.pdf>) identified
303 the importance of how we approach AMR engagement; “How an issue is ‘framed’- explained
304 and presented through specific themes and angles- can influence how it is received by an
305 audience”. Informed by a multi-phase international research project, the report outlined a
306 ‘Framing Toolkit’ identifying five principles in how AMR-communication and outreach
307 should be framed; (i) frame antimicrobial resistance as undermining modern medicine, (ii)
308 explain the fundamentals succinctly, (iii) emphasise that this is a universal issue; it affects
309 everyone including you. (iv) focus on the here and now, (v) encourage immediate action. In
310 co-ordinating these frames, you are likely to create communication that informs, motivates and
311 persuades.

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

323 We adopted such approaches when designing the content of the 'Superbugs' shop. We
324 did not shy away from showing the symptoms and wider burdens of particular examples of
325 infections, and the broader implications of AMR in the failure to treat these, which highlighted
326 the current impact of drug-resistant infections, rather than projections or apocalyptic frames.
327 However, alongside this was a message of positivity, detailing the many strategies by which
328 we are fighting the AMR issue, illustrated using multiple examples relevant to the audience we
329 were engaging. This included improvements to sanitation, agricultural use, surveillance, and
330 the development of new drugs and vaccines, demonstrating how drug-resistant infections are a
331 cross-cutting threat across all of society (beyond specific disease areas). Further to this we
332 provided many sources of information on how the stakeholders can play an important role in
333 the fight, framing the issue as solvable and providing specific calls to action e.g. complete a
334 full course of antibiotics when prescribed. In order to be as inclusive as possible, and in line
335 both with the recommendations of the Welsh Government and the specifications of the original
336 grant remit, all activities and information sheets were available bilingually, in both English and
337 Welsh.

338 It was decided early on in the project to avoid making any assumptions as to prior
339 knowledge of the topic of AMR on the stakeholders, as to not compromise our overall message.
340 As such, it was a concerted decision to begin the narrative of the event on the very basics of
341 microbiology and bacteria that live in, on and around us, before introducing the ideas of
342 infection and treatment. At the forefront of our messaging was an emphasis that AMR is a
343 universal issue, and that anyone could be affected. The project included explanations of the
344 part that human activity is playing in accelerating the issue. In this way we hoped to engage
345 the public in AMR from an informed position on their part. Two ECRs working in the area of

346 AMR were recruited to work alongside the core team's scientists to form a 'scientific content'
347 team, to develop the narrative and details of the exhibition. A description of the stations open
348 to the stakeholders can be seen in Figure 4. Title cards on the wall and hanging from the ceiling,
349 alongside bacterial 'footprints' indicated the suggested route around the shop, but visitors were
350 welcomed to engage on their own terms.

351

352 **6. Project Output**

353 *6.1 Evaluation Strategy*

354 It is widely acknowledged that rigorous and impactful evaluation of public engagement events
355 is challenging, particularly in multi-faceted projects such as 'Superbugs'. We not only wished
356 to evaluate our ability to improve the awareness of AMR, but also evaluate the forum of a pop-
357 up science shop itself as an effective public engagement delivery strategy. To achieve this, we
358 took a multidimensional approach, collecting data in a number of varying ways to provide as
359 detailed a dataset as possible, with reference to a common evaluation framework proposed by
360 Reed *et al.*, (2018). This framework provided a philosophical backdrop for our evaluation
361 strategy and we will adopt a number of the principles outlined within, in future iterations of
362 our 'Superbugs' events. As part of our evaluation strategy, the team reviewed the possible
363 outcomes and impact of the novel project approach through development of a logic model
364 (Figure 2), exploring the inputs, outputs, activities, outcomes and impacts of the project. This
365 was adapted on numerous occasions to ensure feasibility and reach.

366

367 *6.2 Qualitative Output*

368 Over the course of two weeks, we welcomed a total of 6,566 visitors to 'Superbugs'. This
369 vastly exceeded our expectations of 1,000-1,500 per week (modelled on previous pop-up shop
370 examples, and as such we had to adapt quickly to meet the overwhelming need for consumable
371 elements of the shop (arts & crafts, culture plates for Station 4, questionnaires and sticker
372 cards). Typically, visitors explored at the event for anything between 10 minutes to 1 hour.

373 Questionnaires were completed by 10% (n=656) of visiting parties, which is
374 particularly impressive when taking into account that a significant number of our stakeholders
375 were family groups with, in many cases, one parent/child completing a questionnaire on behalf
376 of the whole family. Returning a completed questionnaire to the organisers was incentivised
377 by entry into a twice-daily prize draw, where the winners won a bag of 'Superbugs'-branded
378 prizes. Station 5 ('Create your own microbes') produced over 500 pieces of artwork, many of
379 which adorned the walls of the shop throughout the event and featured prominently in our

380 social media campaign. Over 300 items of activities and reading material were taken away
381 from Station 5 by visitors. At Station 4 ('Grow your own microbes') we generated 2,169 swab
382 plates, with the subsequent social media posts garnering over 2,500 views.

383 Owing much to these swab photos, our social media presence gained significant interest
384 (Figure 6). The Systems Immunity Research Institute Facebook page, where we posted the
385 swab photos (<https://www.facebook.com/SystemsImmunity>), saw a 233% increase in traffic
386 over the course of the event, with 6,000-9,000 new weekly organic impressions and 2,000
387 direct hits on the official 'Superbugs' website at Cardiff University. On Twitter, we saw over
388 140,000 impressions across the three main Twitter accounts promoting the event;
389 @JTyrrell_Micro, @CUSystemsImmu and @CUMedicEngage. As the official Twitter page
390 for the School of Medicine, @CUMedicEngage saw a 20% increase in followers over the
391 course of the 'Superbugs' event. The Twitter hashtag #CUSuperbugs evidences the positive
392 experiences of individuals accessing the AMR public engagement with research interactive
393 science shop and provides a visual and storytelling narrative of the public experience.

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418 **Figure 4:** A outline of the Stations of 'Superbugs: A Pop-up Science Shop!'

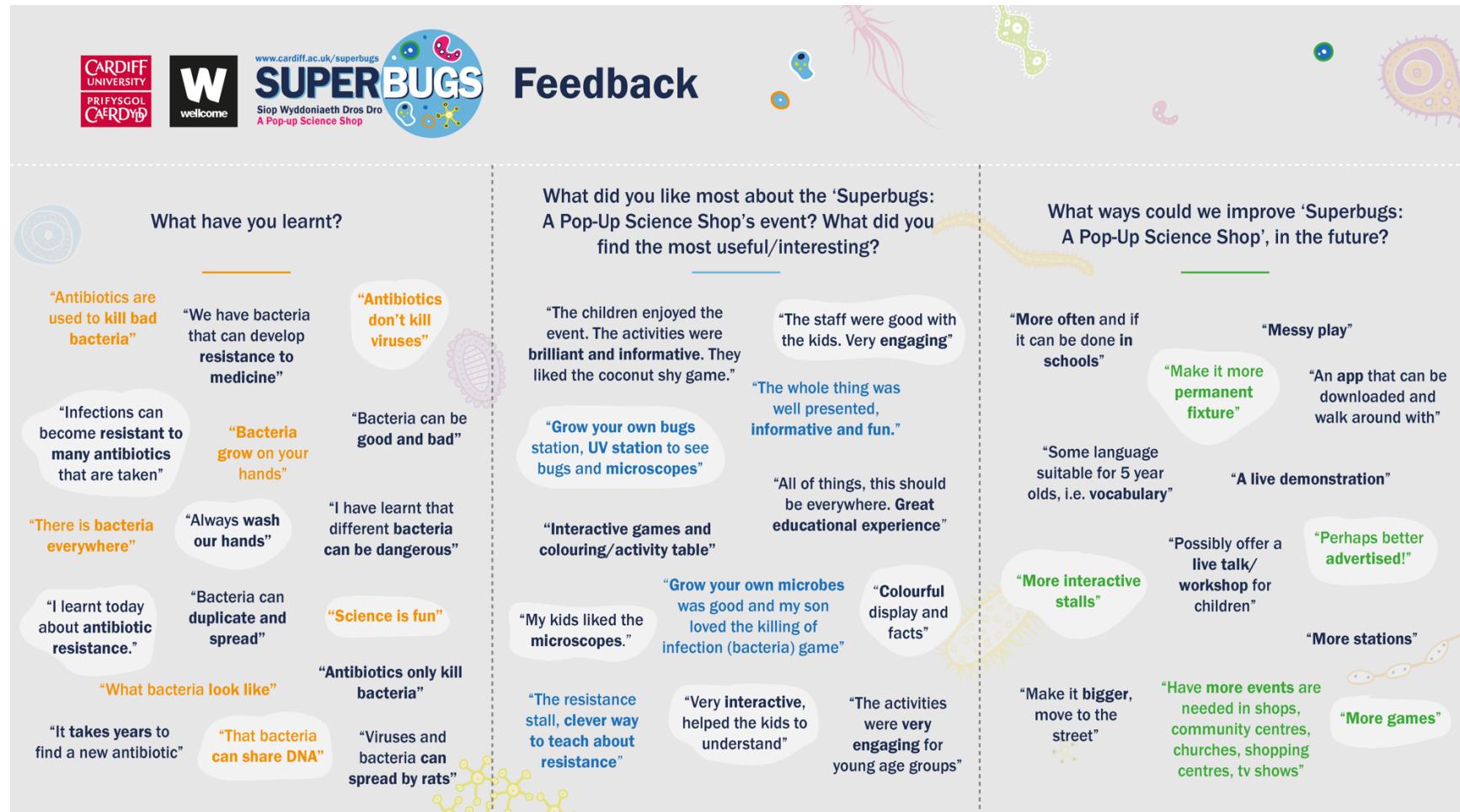
	<p>WELCOME: Visitors were greeted at the entrance, received general information about the event and were invited to take part in an initial benchmarking exercise to evaluate initial AMR awareness- answering some basic questions by placing pipette tips into labelled conical flasks.</p> <p>SAY HELLO TO BACTERIA: Information board introducing visitors to the bacterial world. Children had the chance to interact with cuddly microbe models (courtesy of GiantMicrobes®). We also had a handwashing activity, to illustrate how easy it was to miss parts of your hands when cleaning, through the use of special gel that glows under UV light.</p> <p>A MICROBIAL WORLD: An artwork illustrating a microbe-dominant world and the bacteria in, on and around us. We presented bacterial growth from a host of household locations (i.e. carpet, sink, bins) and different body parts (i.e. skin, nose, tongue, ears), using an exhibition format.</p> <p>GROW YOUR OWN MICROBE: Visitors given the opportunity to swab parts of their body onto agar plates used to culture bacteria. The plates were then taken away and grown under optimal conditions. Anonymised photos of what was grown were posted on a special Facebook album for the visitors to view using unique codes provided on the day</p> <p>CREATE YOUR OWN MICROBES: Arts and crafts corner to create microbial art. Also the chance to dress up as a lab scientist. We provided microbiology-related quizzes, word searches and puzzles. For the adults we provided reading material on and promotional material advertising other engagement events and opportunities offered by the School.</p> <p>MICROSCOPE WORLD: Visitors were able to use microscopes, where they were able to see bacteria of different shapes, sizes and colours such as <i>Escherichia coli</i> (Gram-negative rods) and <i>Staphylococci</i> (Gram-positive cocci), <i>Neisseria</i> (Gram-negative cocci), and <i>Clostridium</i> (Gram-positive rods).</p> <p>BACTERIAL INFECTION VS ANTIBIOTICS: Provided information about the timelines of significant infections through history, and introduced the concepts of antibiotics, what they are, and how they work in treating infection</p> <p>ANTIBIOTIC RESISTANCE: A coconut-shy game, with participants throwing 'antibiotics' at 'antibiotic susceptible' bacteria (those coconuts that could be knocked over), and 'antibiotic resistant' bacteria (those that could not be knocked over) to illustrate the differences and consequences of resistance in treating infections</p> <p>HOW RESISTANCE SPREADS: We emulated a 'ring-toss game' with a 'plasmid-toss game', where players would take the role of a bacterium and try to throw 'DNA' onto our bacteria model. The aim of was to teach the visitors how antibiotic resistance genes may be passed from one bacterial cell to another.</p> <p>WHAT HAVE YOU LEARNT: This was a reflection station, where visitors were invited to post comments and thoughts about their experience on our 'bacterial thought tree'. Additionally, this was the location of our second set of benchmarking, to contrast the performance of our visitors at the beginning of the experience.</p> <p>FIGHTING BACK: Outlined how the scientific community were combatting the issues of AMR, and the roles they themselves could play themselves. Children were encouraged to enter our 'antibiotic discovery ball pit' where they were blindfolded and asked to to hunt for new 'antibiotics'.</p>
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420 **Figure 5:** Word clouds summarising feedback received by visitors.

421 (A) Summary of the feedback received from 116 visitors on the 'bacterial thought' tree.

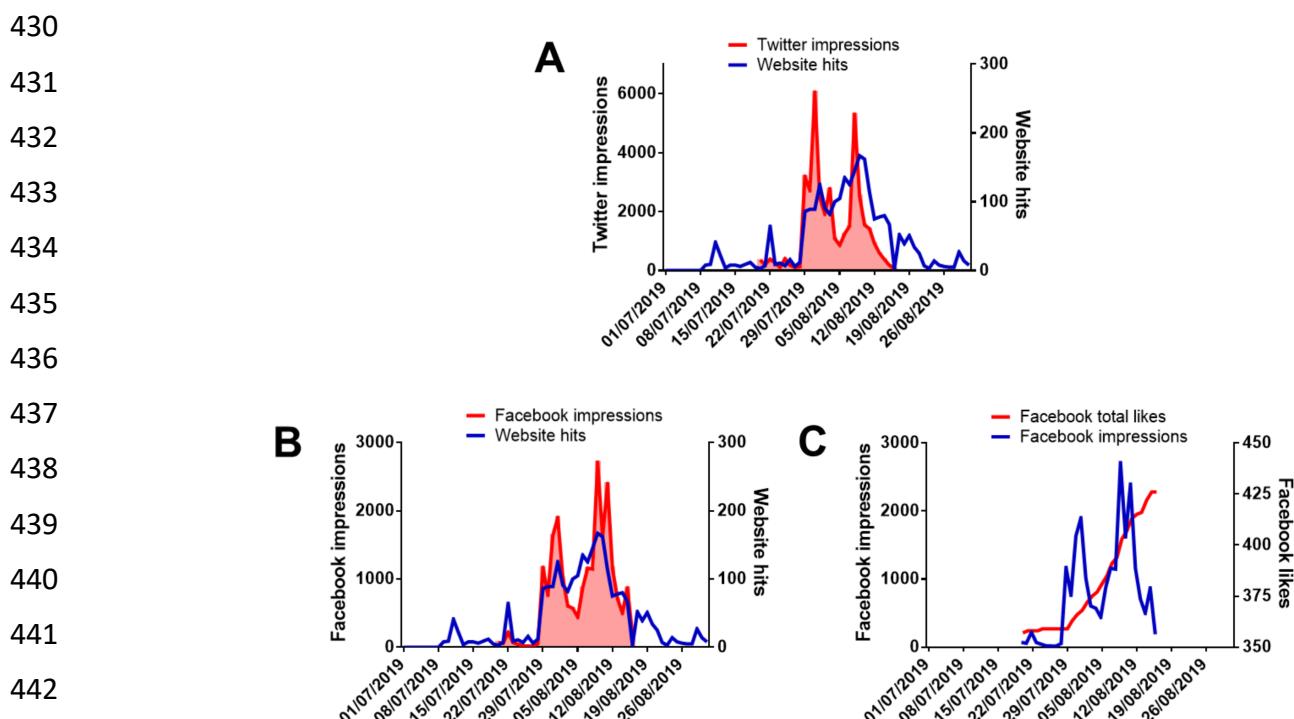
422 (B) Summary of 202 responses: "What did you like most about the 'Superbugs: A Pop-Up Science Shop!' event? What did you find the most useful/interesting?".

423 (C) Summary of 53 responses to: "What ways could we improve 'Superbugs: A Pop-Up Science Shop!', in the future?"



424

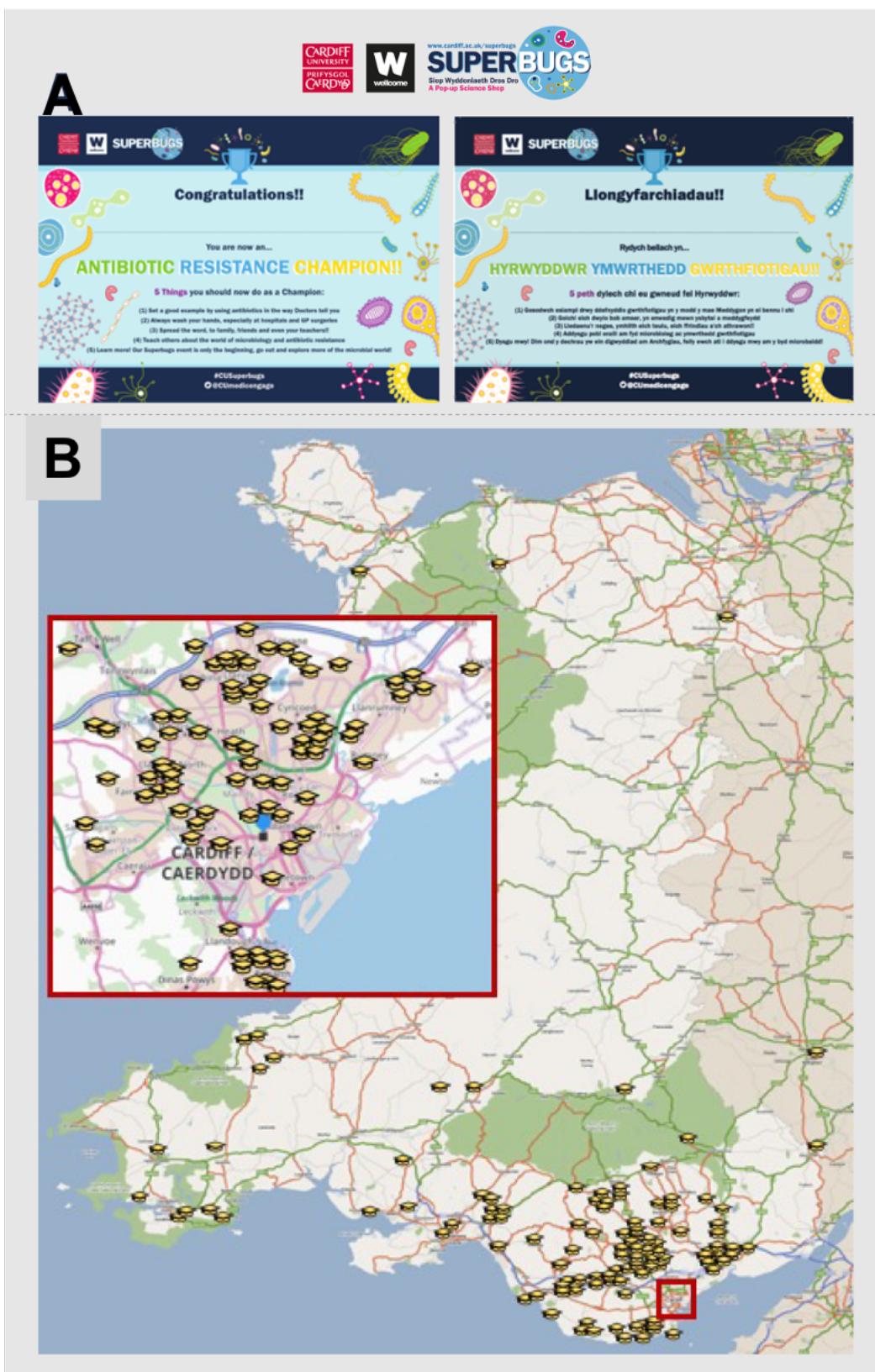
425 **Figure 6: Social media activity and web traffic before, during and after the ‘Superbugs’ event.**
426 **(A)** Time course of direct hits on the ‘Superbugs’ website (www.cardiff.ac.uk/superbugs/) and impressions on the
427 @CUSystemsImmu Twitter account; **(B)** Time course of direct hits on the ‘Superbugs’ website and impressions
428 on the SystemsImmunity Facebook account; **(C)** Time course of impressions on the SystemsImmunity Facebook
429 account and development of Facebook followers.



6.3 Antibiotic Resistance Champions

At Station 1 each young visitor was given a sticker card, corresponding to 6 different activities throughout the shop (Stations 4, 5, 6, 8, 9 and 11; Figure 4). Once all 6 stickers were collected they were awarded the title of Antibiotic Resistance Champion, their choice of ‘Superbugs’-branded prize (pen, bookmark, badge or balloon) and a certificate with handy tips of how they can help in the fight against AMR (Figure 7). We created 1,626 Antibiotic Resistance Champions, from across 200 different schools in Wales, and many further afield (Figure 7). This approach 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).

459 **Figure 7: Antibiotic Resistance Champions:** (A) Bilingual Antibiotic Resistance Champion certificate; (B)
460 Distribution of schools at which the new Antibiotic Resistance Champions attended at the time of the event. Other
461 Champions were created in England and internationally (France, Belgium, Spain, Jersey Channel Islands and
462 Kuwait).



464 *6.4 External Outputs*

465 The event received a notable amount of local media attention. We were involved in a fun
466 feature on the ‘Josh & Kally show’ for Capital FM South Wales. The radio presenters were
467 invited to swab themselves live on air, and we returned the next day to deliver the results as to
468 who grew up the most microbes. This was a unique way to engage a young demographic in the
469 topic of bacteria and to inform wider groups about the ongoing ‘Superbugs’ event. The local
470 television station Cardiff TV spent over an hour in the shop filming visitors engaging with our
471 activities, and interviewing members of the ‘Superbugs’ team. Two videos were produced and
472 shown repeatedly across the local area for the remainder of the event and can be found at the
473 events homepage (<https://www.cardiff.ac.uk/systems-immunity/engagement/understanding-science/superbugs-a-pop-up-science-event>).
474

475 We were also able to raise interest and attention from high profile stakeholders
476 including Kirsty Williams AM (Welsh Minister for Education & Skills) and a visit from the
477 local Member of Parliament for Cardiff Central, Jo Stevens (the current Shadow Secretary of
478 State for Digital, Culture, Media and Sport), in addition to tweets/retweets by a number of
479 Welsh journalists. Jo Stevens took part in a number of ‘Superbugs’ activities, including
480 swabbing her mobile phone to grow any contaminating microbes, and wrote a blog about her
481 experience.

482 More recently, ‘Superbugs: A Pop-up Science Shop!’ was accepted as an entry to the
483 National Co-ordinating Centre for Public Engagement (NCCPE) ‘Engage 2020’ conference
484 that took place online from 30th November – 4th of December 2020. Our video submission
485 can be found on YouTube in NCCPE’s ‘Examples of Practice’ playlist
486 (<https://www.youtube.com/watch?v=NuPnWqz8FdU&t=1s>).
487

488 **7. Impact of Project**

489 *7.1 Impact on Public Engagement Delivery Strategy*

490 A primary aim of ‘Superbugs: A Pop-Up Science Shop!’ was to evaluate this form of public
491 engagement, a novel scheme for both the School of Medicine, and Cardiff University as a
492 whole. We hypothesised that this mode of delivery would be successful in reaching a wide
493 demographic, beyond the limited cohorts who would typically seek out opportunities to engage
494 in scientific research. Questionnaire data collected showed that indeed 67.3% of entries were
495 impromptu visits with no prior knowledge of the event before spotting it on the concourse of
496 StD (Figure 8). This was significantly higher than those visitors indicating any awareness due
497 to aspects of our promotional campaign, including advertisement in the Primary Times

498 magazine, website and social media. Whilst confirming our hypothesis, it was also a triumph
499 for the imaginative and imposing exterior designed by our team and informed by our focus
500 group. This also suggests that in future public space located engagement events, significant
501 resources may be better focused on providing the best and most attractive possible experience
502 for visitors, as opposed to an overly enthusiastic promotional campaign.

503 The importance of our focus group in shaping the nature of the content and the overall
504 design theme for ‘Superbugs’, and the impact this then had on the success of the event,
505 illustrates the potential in utilising focus groups, public involvement and co-production in
506 shaping such projects. We hope this leads to developing a culture of increased efforts for co-
507 production and public involvement across the School of Medicines engagement activities, to
508 the benefit of the scientists and public alike.

509 Further confidence in our strategy was corroborated in the data collected through our
510 questionnaires (Table 2). 95% and 91.9% of visitors, respectively, agreed/strongly agreed that
511 the event was fun, engaging and informative, and that we had pitched the intellectual level
512 appropriately. We are very proud to say that over 94% of visitors indicated that they not only
513 rated ‘Superbugs’ as ‘Very Good’ or ‘Excellent’ but, perhaps even more significantly, they
514 would also recommend ‘Superbugs: A Pop-Up Science Shop!’ to others.

515 Following a visit, Professor Kim Graham, Pro-Vice Chancellor for Research,
516 Innovation and Enterprise at Cardiff University and Professor Gary Baxter, Pro-Vice
517 Chancellor for the College of Biomedical and Life Sciences at Cardiff University took to social
518 media with positive tweets of their experience and encouraged others to visit the shop and
519 event. This engagement from senior leaders at the University highlighted the high-level
520 support for the Superbugs project and public engagement with research. Future conversations
521 were invited from senior leaders, to explore this model of engagement, its potential for societal
522 change and how such activities can be sustained in the longer term.

523

524 *7.2 Impact on AMR Awareness for Stakeholders*

525 We may assuredly accept the hypothesis that our pop-up shop was an effective way of
526 imparting positive impact on the AMR awareness of the public audience with whom we
527 engaged. Table 2 illustrates that ‘Superbugs’ improved the understanding of the world of
528 microbes, antibiotics (and how they work) and antibiotic resistance in 92.7%, 92.5% and 91.7%
529 of cases, respectively. Perhaps more significantly, our evidence supports a progressive
530 influence on future behaviour and attitudes towards antibiotic stewardship, with 90.8% of
531 participants now more likely to complete a full course of antibiotics. Improved antibiotic

532 stewardship has significant and far-reaching implications for our ability to control AMR
533 pathogens (File *et al.*, 2014)

534 Secondary to this, we may infer far-reaching legacy impact of our event. 1,626 young
535 people left not only bestowed with the title of ‘Antibiotic Resistance Champion’ but also with
536 their certificate detailing tips on how they can further their knowledge and spread the word
537 long after the doors of ‘Superbugs’ had closed. As a testimony to the success of this approach,
538 91.3% of visitors completing the questionnaire stated they would pass on what they had learnt
539 at the event (Table 2).

540

541 **Table 2:** Percentage of stakeholders that selected ‘Agree’ / ‘Strongly Agree’ with the below statements.

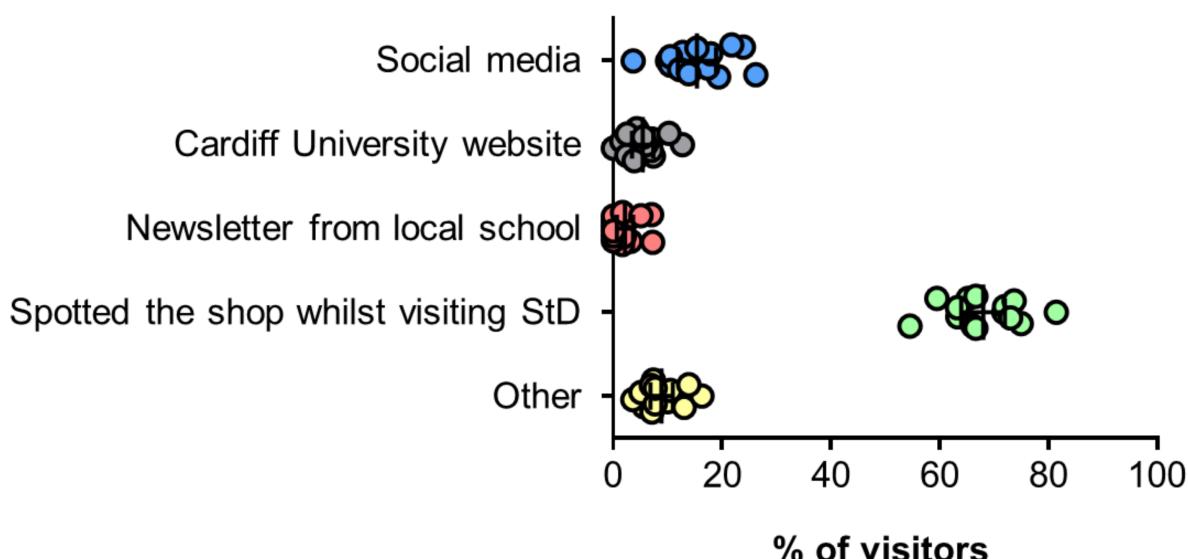
542 Data collected from questionnaires (n=656).

	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

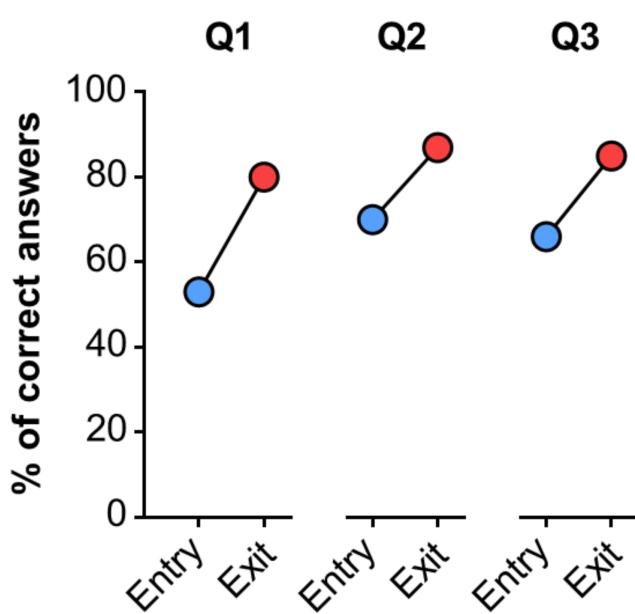
543

544

545 **Figure 8:** 'Where did you hear about Superbugs: A Pop-up Science Shop!' [Questionnaire Q9]
546 (A) Social media (Facebook, Twitter), including Primary Times; (B) Cardiff University website; (C) Newsletter
547 from local school; (D) Spotted the shop whilst visiting StD; (E) Other. Data collected from questionnaires over
548 14 consecutive days (n=656 in total). Individual data points show daily answers; error bars show mean values and
549 95% confidence intervals.



550
551
552 **Figure 9:** Comparison of correct answers to benchmarking questions by Stakeholders on Entry and Exit to
553 'Superbugs' Benchmarking questions are listed below with correct answers underlined.
554 [Q1] "Antibiotics are used to kill....." (A) Viruses, (B) Bacteria, (C) Fungi, (D) All of the above.
555 [Q2] "When taking antibiotics you should....." (A) stop when you feel better, (B) Take all the antibiotics as
556 instructed by your doctor, (C) Save some for next time you feel unwell, (D) Share them with your friends.
557 [Q3] "Antibiotic resistance is a problem for....." (A) only people taking antibiotics, (B) Everyone, (C) The elderly
558 & sick, (D) Those who travel to exotic countries.



560 7.3 *Impact for the Institute and Staff*

561 ‘Superbugs’ provided a valuable opportunity for professional development for all involved.
562 For the lead scientist, it was their first experience of independently securing grant funding, and
563 the organisational and administrative responsibilities that comes there-in.

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

577 As described, we saw an incredible response to our Station 5 ‘Grow your own microbe’
578 activity, where visitors were able to swab themselves and then using a unique code, follow up
579 on what grew at a later date online. The enthusiasm with which visitors engaged with this
580 suggests at a potential rich resource that could be exploited for research purposes and could
581 provide a unique insight into the social and environmental spread of target micro-organisms,
582 and the anthropogenic factors driving this dissemination.

583 ‘Superbugs’ instigated a significant influx of activity and attention onto the social
584 media and web pages of the School of Medicine public engagement team. Across the academic
585 year, the School of Medicine delivers a wide portfolio of engagement activities for students of
586 primary and secondary schools, and the wider public, including a free-access Public Lecture
587 Series, the Wales-wide Life Sciences Challenge quiz and the ‘Science in Health Live!’ event
588 and laboratory work experience scheme which both provide unique opportunities for year 12
589 school pupils to visit the working environment of the University Hospital of Wales in Cardiff
590 (<https://www.cardiff.ac.uk/medicine/about-us/engagement>) witnessing cutting edge
591 technologies and research first hand.

592

593 7.4 *Access for protected characteristics*

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

607

608 **8. Discussion**

609 *8.1 Summary of Principal Findings*

610 To our knowledge this is the first pop-up science shop designed to increase the awareness and
611 knowledge of the general public of the microbial world, infection biology and the increasing
612 threat of antibiotic resistance to global public health. Attracting 6,566 visitors in a two-week
613 period during the summer school holidays indicates a strong thirst for such engagement in
614 research by members of the public.

615 Based on the qualitative and quantitative data collected, the anecdotal feedback
616 received, and personal communication from senior academic colleagues across the School of
617 Medicine, we are confident in concluding that ‘Superbugs: A Pop-up Science Shop!’ made
618 positive strides in raising awareness of the AMR crisis and educating the public of the part they
619 need to play in the fight against this global issue. The data presented herein indicates that we
620 have met the aims we set and achieved the outputs we had strived for at the beginning of the
621 ‘Superbugs’ project. We created an environment of two-way dialogue with wide and varied
622 public demographics, imparting a positive change in the awareness of microbiology and AMR.
623 Concurrently, ‘Superbugs’ has illustrated the efficacy of public space-based engagement in
624 doing so.

625

626 *8.2 Limitations and Future Improvements*

627 ‘Superbugs’ was delivered in one city centre location, Cardiff (Wales’s capital). It is the
628 ambition of the project team that future redeliveries of ‘Superbugs’ events would act to widen
629 the accessibility to include other cities and towns across Wales, particularly those outside of
630 southern hubs. This would enable us to compare the impact of ‘Superbugs’ across different
631 geographical and socio-economic areas, of more diverse stakeholder demographics, and
632 provide deeper data sets with which to evaluate the efficacy of our engagement model.

633 As has already been indicated, this project was built on upon the time and hard work of
634 the core project team, and the willingness of an army of volunteers to give up their own time
635 to participate. In the lead-up to the event itself, we began a recruitment drive through the
636 communication networks of the School of Medicine, and more widely the College of
637 Biomedical Life Sciences. Regrettably, uptake outside of the research groups of the involved
638 academics was limited, and as such at certain times numbers during the event were limited to
639 the point of threatening to compromise the experience of our visitors. Notwithstanding,
640 ‘Superbugs’ presented a valuable, but for many a missed, opportunity to develop
641 communication and outreach skills, and gain insight into how public engagement activity with
642 research may support the development of pathway to impact statements. It should be noted that
643 one potential contributor of this was the timing of the event during the summer holidays,
644 perhaps suggesting the importance of budgeting of staff time in the organisation of large-scale
645 engagement and outreach events.

646 This also highlights an intrinsic issue within the academic culture and attitudes towards
647 public engagement activities. Historically, public engagement may be seen simply as a way in
648 which to educate the ‘scientifically illiterate’. As such, the discipline of public engagement has
649 been underserved in time, attention, funding, and willingness to participate (as evidenced here)
650 by academic institutions and the staff therein. Perhaps nothing more than a pleasantry aside to
651 the primary roles of researchers. This is further exacerbated by an environment that prioritises
652 quantifiable publications and grant funding in determining career prospects and progression.
653 This apathy is somewhat counterintuitive given all science, at it’s very foundation, is for the
654 betterment of the human condition and those we seem reluctant to communicate to.

655 The introduction of ‘impact’ (encompassing public engagement) as an element of
656 assessment for REF 2014 is perhaps a clear signal of a slowly changing tide in this regard
657 (Copley, 2018). Increasingly, public engagement may be seen as a tool to raise an institutes
658 profile, influence policy makers (both directly and indirectly) and further quantify research
659 impact. However, a paradigm shift in the way in which public engagement with research is
660 regarded at all levels of academia is still needed. More standardised frameworks for the design,

661 implementation and evaluation of public engagement activities are required to advance the
662 integrity and rigour of this capacious discipline, and there is a growing literature to achieve this
663 (Mahony and Stephansen, 2017). Furthermore, as the demand for public engagement with
664 research activities continues to increase from funders, concern around recognition, value and
665 support amongst employers requires further exploration.

666

667 **9. Conclusion**

668 Currently, we as a society are facing the challenges of the COVID-19 pandemic. It would be
669 remiss however, to entertain any oversight of the more silent pandemic of AMR that has been
670 with us for decades and continues to carry severe impact economically and on public health.
671 Increasingly, a consensus view is emerging that the COVID-19 pandemic actually threatens a
672 further exacerbation of the antibiotic resistance crisis worldwide (Miranda *et al.*, 2020; Murray,
673 2020). An alternative view holds that the reduction of international travel may prohibit the
674 global dissemination of AMR pathogens, and scientific communication regarding this viral
675 pandemic may infer improved awareness around the appropriate use of antibiotics (Murray,
676 2020). It is clear then that there will be a post-COVID-19 impact on AMR, even if the true
677 nature and parameters of these are not yet known (Monnet and Harbarth, 2020). Either way, it
678 is evidently pertinent to continue effective and impactful engagement of the public on the topic
679 of infectious disease.

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

692 Increasing public awareness around AMR and antibiotic use now forms a cornerstone
693 of the UK government’s 20-year strategy in managing and controlling the issue
694 (www.gov.uk/government/publications/uk-20-year-vision-for-antimicrobial-resistance).

695 Redfern *et al.*, (2020) comprehensively outlined a number of activities, representing a diverse
696 range of approaches that have been implemented to this end, and in doing so highlights a most
697 pertinent point. Simply, in undertaking a systematic review of AMR-related engagement
698 activities, an intrinsic limitation was the relative paucity of publications based on such
699 activities. Indeed, there is a similar such problem for microbial literacy within the public and
700 education sectors also (Timmis *et al.*, 2019) and this is further reflected in the Wellcome Trust's
701 'Reframing Resistance Report' (<https://wellcome.org/sites/default/files/reframing-resistance-framing-toolkit.pdf>). We hope that accounting 'Superbugs: A Pop-Up Science Shop!' herein
702 we will contribute to a growing body of work laying the foundations to address such a problem,
703 and in doing so leave a lasting impact on addressing public awareness of the AMR threat, and
704 the best practices to achieve this aspiration.

705

706 10. Notes on Contributors

707 **Dr Jonathan M. Tyrrell** is a Lecturer in Medical Microbiology and Antibiotic Resistance at the School of
708 Cellular & Molecular Medicine, University of Bristol. As a passionate scientific communicator Jonathan became
709 involved in a number of engagement activities, leading to him creating 'Superbugs: A Pop-Up Science Shop'.
710 Jonathan was lead scientist on the 'Superbugs' and was responsible for the conception, and involved in all
711 following facets, of the project.

712 **Ms Christie Conlon** is a professional graphic designer for Cardiff University's College of Biomedical & Life
713 Sciences and the BBC. Christie was the graphic artist of the project and was responsible for the design of the shop
714 interior, exterior, logos, certificates and give-aways produced by the project.

715 **Dr Ali F Aboklaish** is a research associate working on antibiotic resistance in the School of Medicine, Cardiff
716 University. Ali assisted in the administrative, planning and delivery of the project and was also a member of the
717 'Science content' team that designing the information and activities delivered.

718 **Mrs Sarah Hatch** is Cardiff University's School of Medicine's Engagement Manager. Sarah led on the
719 organisation of the project's focus group ensuring the project's target audience informed the development,
720 delivery and subsequent output of the proposed engagement activity. Sarah also took a significant role in
721 developing the evaluation strategies of the project.

722 **Mr Carl Smith** is the Public Engagement Manager at Cardiff University. Carl was an advisor from the earliest
723 stages of the project and volunteered for the delivery of the event.

724 **Mr Jordan Mathias** is a research assistant working in the field of antimicrobial resistance in the School of
725 Medicine, Cardiff University. Jordan was part of the 'Science content' team, designing the information boards
726 and activities within the shop. Jordan has now joined the core team, helping to deliver the next stages of our
727 'Superbugs' project.

728 **Ms Katy Thomson** is a PhD student working in the field of antimicrobial resistance in the School of Medicine,
729 Cardiff University. Katy was part of the 'Science content' team, designing the information boards and activities
730 within the shop.

732 **Professor Matthias Eberl** is Professor of Translational Immunology and Academic Lead for Public Involvement
733 and Engagement at the School of Medicine, Cardiff University. Matthias was instrumental in the strategic design,
734 delivery and evaluation of ‘Superbugs’.

735

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744 and interior design and fitting of ‘Superbugs’ was unwavering and beyond the call of duty. A thank-you to the
745 British Society for Immunology who provided important support to our grant application and to the event. Finally,
746 a thank you to GiantMicrobes® for their generous provision of cuddly microbes to be used as display items and
747 prizes to be won.

748

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755

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