

Outreach

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Outreach: Impact on Skills and Future Careers of Postgraduate Practitioners Working with the Bristol ChemLabS Centre for Excellence in Teaching and Learning

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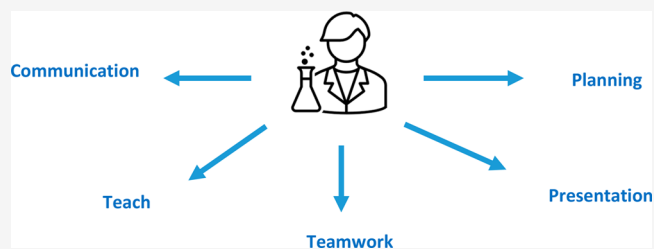
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Supporting Information

ABSTRACT: Postgraduate engagement in delivering outreach activities is more commonplace than it once was. However, the impact on postgraduate students (typically studying for a Ph.D. degree) of participating in the delivery of these outreach activities has rarely, if ever, been recorded. The Bristol ChemLabS Outreach program has been running for ca. 17 years, and in that time, many postgraduate students have been involved (approximately 500), with around 250 typically for up to 3 years. We sought to investigate the impact of outreach engagement on postgraduate alumni who were involved in the program for over 3 years (32) and how the experiences and training of the outreach program had impacted on their careers postgraduation. Thirty of the 32 postgraduates engaged and ~70% reported that their outreach experience had influenced their decision making on future careers. Many respondents reported that the skills and experiences gained through outreach participation had contributed to success in applying for and interviewing at their future employers. All respondents reported that outreach had helped them to develop key skills that were valued in the workplace, specifically, communication, teamwork, organizational skills, time planning, event planning, and event management. Rather than a pleasant distraction or an opportunity to supplement income, all participants noted that they felt there were many additional benefits and that this was time well spent. Outreach should not be viewed as a distraction to science research but rather an important enhancement to it provided that the program is well constructed and seeks to develop those delivering the outreach activities.

KEYWORDS: Higher Education Institutes and Outreach Funders, Public Understanding of Science/Outreach, Thematic Content Analysis with a Deductive Approach



INTRODUCTION

Higher education institutes across the world engage in outreach programs with primary^{1–7} and secondary students^{8–12} and members of the public. STEM (Science, Technology, Engineering, and Mathematics) departments run a variety of programs to promote their subject, disseminate current research, introduce school students to higher education, and support teachers and educators.^{13–15} STEM departments in higher education institutions are considering impacts on the institution, recruitment, those delivering the outreach, and society. There are many reasons, other than driving student recruitment, to support outreach including the following:

- building partnerships with local communities (e.g., schools), interest groups (e.g., local businesses, guiding/scouting groups),¹⁶ regional organizations (e.g., business,

charities), national bodies (government, national organizations such as Learned Societies), and even international stakeholders (e.g., NASA),

- training of external and internal staff and students,^{17–24}
- knowledge exchange with an overarching objective to enhance the capacity of the institute.^{25–29}

In science departments and especially chemistry departments in the United Kingdom, outreach is an important and valued

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activity. Given the exacting nature of laboratory studies in chemistry (health and safety, use of advanced and expensive equipment, technical knowledge, and support), higher education institute's support of school students in their development of practical skills can have a significant impact not only on their cognition but also on their future career.^{30,31}

The School of Chemistry at the University of Bristol was awarded a Centre for Excellence in Teaching and Learning (CETL) in 2005 called Bristol ChemLabS.³² Its outreach program was tasked with bringing a wide range of stakeholders to the CETL to work with it through a program that engaged as wide a group as possible. The program has been in existence for 17 years and for the last 9 years has engaged between 20 000 and 40 000 students, teachers, and members of the public in face-to-face outreach annually. The project relies heavily on postgraduate chemists to deliver many aspects of the project.^{33–36}

In this paper, we investigate what impact, if any, outreach participation with Bristol ChemLabS has had on the careers of participating postgraduates. Undergraduates seldom have appropriate time slots available for such activities without missing lectures, tutorials, laboratory work, or workshops unless engaged in final year school projects.³⁷ Hence, this program is driven by postgraduate students. Therefore, the research question the paper seeks to answer is “What effect has participation in outreach delivery had on the careers of participating postgraduate students?”

ETHICS

The respondents were given the guarantee of nonattributable comment and were offered coauthorship. They had the right to challenge and correct what was being written, and they were asked to approve a final version of the manuscript regardless of authorship. The questionnaire used was approved before use by the University of Bristol, Faculty of Science Ethics committee.

DATA COLLECTION METHOD

A questionnaire (see [Supporting Information](#)) was emailed to the last known email addresses of the postgraduates that met the criteria set. The criterion for inclusion was that the postgraduate had participated in the Outreach Programme for more than 3 years; this led to 32 potential participants. The reason for this threshold was that participants were then likely to have taken part in most of the activities, in particular, summer schools and school visits. From the 32 former postgraduate chemists that were contacted, 30 responded. Each of the questions and the responses are reported. It is possible that the two postgraduates who did not respond were contacted using out of date contact details, but the response rate was very high regardless. The respondents gave a wealth of highly detailed feedback. Apart from the personal information in the questionnaire, the questions and their responses are recorded in the [Results and Discussion](#) section.

The responses were analyzed by thematic content analysis where a deductive approach was taken, for which a coding framework was applied.³⁸

RESULTS AND DISCUSSION

Data Associated with the Sample of Postgraduate Students Considered

The 30 participants presented the following information: 19 identified as female, 11 male, and 23 were U.K. nationals. The

participants were engaged in Ph.D. programs that were 3–4 years in duration. Many of the participants continued outreach activities while they wrote up their thesis or wrote papers. During writing up or post completion, several participants then became administrators for the outreach project and continued to participate in outreach events.

The average duration of participation in outreach activities was 4.2 years. If the postgraduate started their Ph.D. program in October 2005, this was identified as participating in outreach in 2005. The number of outreach events per year for each postgraduate was not recorded. Many of the participants continued with outreach while completing their thesis or were temporarily employed in outreach post research.

The spread across the traditional subtopics of chemistry was Organic 11, Inorganic 5, and Physical 14. It should be noted that the Inorganic Chemistry section at the University of Bristol was the smallest research section during this period, and once normalized for the total number of Ph.D. students in each section, the spread is more even. There was a good spread of responses across the project period, 2005–2017 ([Figure 1](#)). No

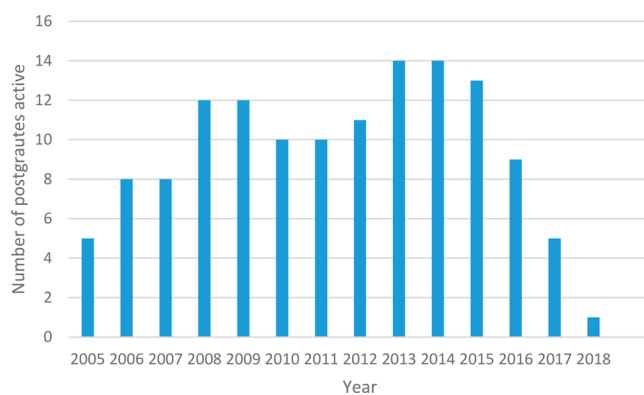


Figure 1. Number of postgraduates per year from the sample that were active in the Bristol ChemLabS Outreach Programme.

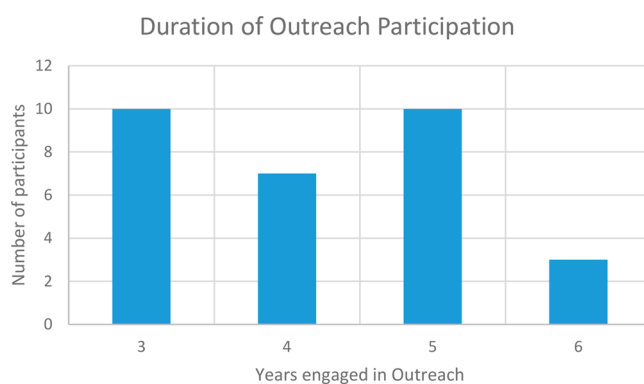


Figure 2. Number of years that participants in the survey³⁰ were engaged in chemistry outreach.

participant was active for less than 3 years ([Figure 2](#)). The engagement was through most of the 3–4 years of the Ph.D. program and additional time during the write-up phase. Several continued outreach through temporary paid employment as outreach administrator, while others continued during their transition into postdoctoral research. Throughout the duration of the project there was also a former postgraduate, employed as

Table 1. Outreach Activity Type and the Numbers of Responders That Participated

activity	description	location	no. of respondents with experience	relevant references
secondary laboratory demonstrations	postgraduates assist school students in the Undergraduate Teaching Laboratories	School of Chemistry, University of Bristol	27	13, 20, 24
lectures	half-hour talks that share the journey the student has made in becoming a research chemist, describing what a postgraduate is and explaining elements of their research at an appropriate level to the audience	School of Chemistry, University of Bristol and elsewhere	17	
summer schools (U.K. students)	chemistry "camps" for senior students (16–18 years old) from U.K. schools that have a duration of 2–5 days and comprise laboratory workshops, lectures, tours, and workshops	School of Chemistry, University of Bristol	21	22
summer schools (overseas students)	these "chemistry camps" for senior students from non-U.K. schools and undergraduates from overseas universities have a duration of 2–4 days and comprise laboratory workshops, lectures, tours, and workshops	School of Chemistry, University of Bristol	12	23
primary experiment circus	a circus of 3 chemistry experiments for primary age classes, each overseen by a postgraduate student	in U.K. primary schools	23	6, 7, 34
spectroscopy in a suitcase (SIAS)	these workshops take the Royal Society of Chemistry's (RSC) infrared spectrophotometers and ultraviolet visible spectrophotometers into schools where they are used by senior school students following a class presentation; this project ceased in July 2020	in U.K. secondary schools	12	
spectroscopy tours	half-day tours of several analytical techniques where the postgraduate chemists are used as guides that deliver 20 min sessions on the use of various instruments	School of Chemistry, University of Bristol	15	36
outreach administration	postgraduate chemists, typically those writing up or following thesis submission, who were very experienced in outreach carried out administration tasks associated with outreach	School of Chemistry, University of Bristol	10	21
assemblies/lectures	science assemblies for primary schools, and lecture demonstrations for secondary schools; a few postgraduates per year were trained to deliver such chemistry demonstrations	in U.K. secondary schools	7	5

a Primary Science Consultant, who was not included in this part of the survey.

Outreach

There is a large portfolio of activities that employ current and past postgraduate chemists in outreach in the Bristol ChemLabS program. Table 1 lists the general categories of outreach and a brief description. Most of the participants surveyed would have engaged in multiple activities.

In addition to face-to-face outreach, many postgraduates have written or cowritten articles, based on their research interests, aimed at senior school students and their teachers. Many of these are listed in the Supporting Information.

Question: "What Positions Have You Held since Leaving Outreach?"

Most positions held by respondents are as expected; postdoctoral research associates (PDRAs), academics, teachers, outreach professionals, or working in science-based industry. Most work in areas related to their degrees. These include positions in the United Kingdom and overseas (Figure 3).

Of the PDRAs, 8 were working in universities in the United Kingdom and 5 overseas (Europe, Africa, Asia, and North America). Of the 4 current teachers, 3 are in secondary

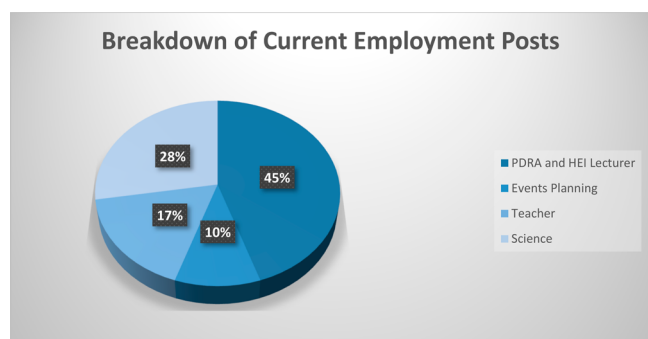
education (2 in the United Kingdom and 1 overseas) and 1 was in primary education (United Kingdom).

Those working in industry have had employment opportunities including forensics, nuclear facility management, business management, start-up companies, oil and gas, and information technology.

Several of the older participants had changed positions and even transferred between categories, e.g., from PDRA to teacher (Table 2). It should be noted that 2 of the original PDRAs had

Table 2. Employment Categories of Outreacher on Leaving University of Bristol and Current Position Category

initial position held	current position held	count
PDRA	PDRA	5
	science industry	4
	academic	3
	teacher (secondary age)	2
	teacher (primary age)	1
	nonscience industry	1
	special events organizer	1
	science industry	science industry
teacher secondary age	teacher secondary age	3
special events organizer	special events organizer	3

**Figure 3.** Categories of current employment for responders at point of writing.

become HEI academics several years before their current posts, i.e., they held academic posts prior to starting a Ph.D. program.

As a general trend for Ph.D. chemists, 30% remained in academia (postdoctoral research, etc.) with 50% of these obtaining jobs overseas and 50% in the United Kingdom, 30% obtained jobs in chemistry-specific roles (e.g., working as a research chemist in pharmaceutical companies), 30% used the broader skills they have developed in wider roles (some scientific, some not) such as patent law, finance, and consulting, 5% went into business for themselves, starting science-based companies (biotech and IT), and the remaining 5% followed passions related to their non-Ph.D. life, often sporting or artistic (School of Chemistry, University of Bristol, survey data).

Table 3. Summary of the Number of Responses and Examples of These Responses to the Question “Did Outreach Did Outreach Affect Your Future Career Choice?”

reason outreach affected future career choice	no. of responses	responses
leading the way into teaching (primary, secondary, or university)	6	“Outreach gave me the opportunity to teach and to work with children over a wide age range. Outreach was the aspect of my Ph.D. that I loved the most and it made me realize the future career that I wanted. I love teaching so much and I am very grateful for the opportunity that doing Outreach gave me to explore a career I never expected to do!”
enjoyment of working with different sorts of people (implication: not just academic/research chemists)	4	Through an administration role—“The admin role also helped me realize I enjoyed dealing with clients and working in a nonacademic role.”
helping to decide on a career in academia compared with industry	3	“I realized how much I enjoyed teaching and inspiring future generations and wish to continue to do this in some capacity in the future. This has especially helped me to choose a career in academia over a career in industry, as there is more scope for teaching/mentoring.”
working for a company/university that engaged in outreach	3	“ChemLabS (sic) was at least as important to my future career as gaining a PhD. If I hadn’t had ChemLabS I doubt I would be working in science now.”
realization that a pure academic career was no longer “desirable”	2	“The outreach program presented me with an alternative career path, which in the end seemed much more appealing than staying in academia.”
increase in confidence	1	“It (outreach) made me more passionate about teaching and improved my confidence.”
enjoying organizing events for others	1	“Greatly enjoyed organizing an event for others to benefit from, put smiles on faces, creating an experience to remember. Wanted to pursue a career related to science-based events.”
love of simplifying science concepts	1	“It was through completing outreach that I realized how much I enjoy interacting with different people, working on a variety of things, and taking highly technical concepts and breaking them down into understandable language.”

Question: “Did Outreach Affect Your Future Career Choice?”

Seventy percent of respondents indicated that outreach had played a part in their career choice, some more directly than others. Four of the postgraduate responders in the sample now have positions working directly in outreach, with one already employing 11 others. Irion²⁵ notes the impact that outreach can have on future careers in the broad area of science communication post Ph.D. degree, but here we see an even wider impact on careers.

Those That Replied Yes

Table 3 summarizes the responses from those that said yes to the question “did outreach affect your future career choice”.

Those That Replied No

Those that said outreach did not play a part in their future careers stated they had already decided what they were going to do as a career or were already engaged in academia in the United Kingdom or overseas before engaging in outreach during their Ph.D. program.

“Outreach did not affect my future career choice directly because I was already holding a position as a faculty member in the Department of Chemistry at... University before joining in outreach.”

There is no formal data on any Ph.D. students engaged in outreach outside this program, but we can compare this with ad hoc work before this program. Among the reasons for establishing this program were a lack of consistent training and support for activities and a lack of opportunities for students to lead and/or devise activities and support for travel and chemicals. Therefore, we know that those who did take part in outreach activities prior to this program were not inclined to progress this area beyond what they had done.

Question: “Did Skills Learned during Outreach Benefit Future Employment?”

Raddon and Sung’s³⁹ report in 2009 (page 15) compiled the core skills developed by postgraduate students of all subjects that are being developed through their doctorate. In response to this survey of chemistry postgraduates, key themes in responses were mostly around the development of transferable skills—the so-called soft skills. These are in great demand by industry.^{40,41} They included the following

- communication (written and oral),
- organizational,
- dealing with responsibility,
- teamwork,
- time management.

Oral Communication. These skills were broken down into translation to an appropriate level of understanding considering the background of the audience, public speaking, and presentational skills. Kompella et al.⁴² noted the importance and impact of supporting researchers to explain their thesis to school students and general audiences and the myriad of benefits that accrue for both the researcher and the audience. Therefore, honing communication skills in general is an important facet of the training.

Quotes. “When I got my first academic post I had no specific lecturing experience, but I was confident in my interview that I could cope easily with lecturing responsibilities based on my experience with outreach lectures.”

“As a [academic] researcher I have to work with all age groups so after outreach I had the knowledge of working with all age groups especially Primary school students where one has to adapt to their level of understanding in order for them to grasp the concept. Outreach really helped.”

“I gave over 15 talks as part of ChemLabS which helped to improve my public speaking. It also improved my ability to engage with a non-academic audience. This was particularly useful when writing grant applications (which often require a “layperson summary”) or blogs for the media.”

“...my outreach experience has definitely improved my presentation skills and confidence presenting and explaining my work.”

Written Communication. Several Ph.D. students per year worked with the School Teacher Fellow^{43–45} to produce articles for magazines and blogsites aimed at senior school students (16–18 years old) and teachers.

Quote. “While I am not really involved in traditional outreach, I am still doing science writing work for two knowledge dissemination magazines (freelance writer) as there is not a lot of established science outreach in Switzerland and I have only recently moved to my new institution...”

Organizational and Planning Skills. Respondents found that outreach activities gave them an opportunity to develop, use, or extend their organizational and planning skills.

Quotes. “[being Outreach Administrator] helped me organise and complete tasks to deadlines and work with clients.”

“Planning, I learnt how to plan and resource a lesson (including appropriate experiments), ensuring correct and appropriate levelled materials were created and available. Within organisation as part of my post-doc I had to communicate the plan and layout of experiments for a day of outreach.”

“The outreach administration position helped me improve my organizational skills. This position was very important for my career since it was my first job outside of academia (research). It taught me how to organise events with large amounts of people, how to interact with clients (schools) and internal collaborators and general admin work carried out in any working set-up environment.”

Teamworking Skills. Working as part of a team to organize and deliver outreach activities for small and large audiences and a range of ages was also valued.

Quote. “The skills learnt doing outreach helped me a great deal in my profession. Developing good communication skills according to various audiences, social interaction, team management, logistics and time management.”

Self-Confidence. The experience of being put solely in charge of a series of lab events helped the postgraduates to develop self-confidence in their own abilities of what they could achieve.

Quote. “Self-confidence/It taught me that if someone believes in you, you can achieve high targets and go beyond the skills you know about yourself.”

“I will never forget the trust that X put in me as I had to replace [them] to give a talk to 300 kids or to run a workshop I had never really done before at last minute which gave me confidence.”

Time Management. Time management skills of postgraduates is something often taken for granted by supervisors. It should not be as the following comment suggests.

“Taking part in outreach also taught me how to manage my time and the work load of my PhD.”

Skills in the Presentation of Practical Chemistry

Several postgraduates per year, typically those heavily engaged in school outreach and who had demonstrated exceptional communication skills could train to give chemistry lecture demonstrations.⁴⁶ To be able to give a lecture demonstration well is a difficult skill to acquire, requiring a thorough understanding of the concepts and accurate terminology, behavioral control of audiences, communication at an age-appropriate level, voice projection, and a thorough understanding of safety and organizational skills.⁴ Those who were able to deliver lectures found a variety of benefits. Besley et al.¹⁸ noted that chemists are the least likely to engage in outreach postgraduation but regard engaging with the public as being important. The health and safety aspects and perception of risk can be a barrier, but researchers in this program have had significant training in planning events, including risk analysis and health and safety. No doubt these are both exceptionally important but are not insurmountable barriers.

Quotes. “Presenting science demo lectures improved confidence, public speaking. Setting up and performing demo lectures/lab demonstrations led me to become more flexible and work better under pressure.”

“The skills learned during Outreach helped me to develop my teaching resource packs (e.g. practical, demonstration lectures) which were applied in public engagement of science during my faculty job in [country outside of UK].”

Event Management

Responses, unexpectedly, also gave credit to skills acquired in the back office of the outreach program.

Quote. “Event management and organisation skills: which I developed in Outreach admin/coordinator role.”

Other Points of Interest

Feedback also revealed that the skills developed through outreach were highly valued, not just to look good on respondents' CVs or to impress people at an interview but useful in the workplace. Irion²⁵ noted the many careers related to science communication that are open to Ph.D. scientists and how, if properly trained, they can be powerful advocates in this arena. Here, we note that some of the cohort in this study have pursued such a career and generously acknowledge the role of the outreach program in opening these opportunities to them and giving them the confidence to pursue such a career.

Quote. “It (outreach) gave me a place to develop skills that were outside the lab—the type of skills I think everyone with a postgrad in science needs and are not always developed: Communication, Empathy, Teaching, Presentation, two-way dialogue and understanding of how science is perceived, working in a team/collaboration, better understanding of science (retained broad knowledge, not just one area).”

Yuan et al.⁴⁷ interviewed 24 science communication trainers who noted that scientists rarely focus on applying two-way communication tactics, such as listening to their audiences or tailoring messages based on their audiences' needs. In this outreach program, researchers were trained in two-way communication as part of the Outreach Programme. Here, the School Teacher Fellow, in particular, whose background was in secondary school teaching, emphasized this essential skill. Yuan et al.⁴⁷ noted that the interviewed trainers recognized the value of two-way communication but seldom addressed this in science communication training.

Question: “Are You Still Engaged in Outreach?”

Seventy percent of the respondents stated that they were still engaged in outreach with others reporting that work or family commitments do not afford time to do so.

Quotes. “Outreach is very much something I would like to resume in the future.”

“Unfortunately, not, full time job takes up too much time. And it would never live up to working with ChemLabS!”

Those respondents in positions that focused on outreach were doing so with numerous engagements, whether school students, teachers, or members of the public.

Example: This outreach worker is now the Public Engagement Manager for a national science facility. “I have developed and managed the science and engineering public engagement program for the [named laboratory]. We engage with over 2000 school students teachers and public on the... Site and another 2000 members of the public off site a year.”

As part of the role, the respondent is charged to develop, train, manage, and deliver the science and engineering public engagement program to develop resources for schools and others. Many of these skills would have been developed while participating in the outreach program at Bristol ChemLabS.

"They [named company created by respondent] have developed tools that have been experienced by over 150 000 people worldwide, including in the last six months: [named product created by respondent] (beta version) is now in 23 secondary schools and 7 primary schools in the UK, 2 international schools (covering secondary) in Germany and 1 international school in China. This currently gives 12500 school children access to [named product]. We had approximately 32 000 people from general public/families experience a 3-month installation in [named UK science center]."

Those in academia were engaged, giving lecture demonstrations, writing for targeted audiences other than academic settings, or running workshops. Some are running their own outreach activities in other universities, both home and abroad.

Overseas-Based Examples of Outreach Continuation

Quotes. *"One of the key areas of performance in my area is community involvement. With the knowledge I gained from the Bristol ChemLabS outreach group, I am doing well in that area and have started the outreach group of my Department which is doing well so far."*

"Annual science camp (100 every year, done so far for 4 years) and sporadic talks (around twice a year)."

Other U.K.-Based Examples of Outreach Continuation

Quotes. *"This year I launched the [named] project—aiming at translating real-world and research chemistry into activities across the school curriculum. We eventually aim to have a fully searchable database of activities targeted from pre-school to A-Level."*

"I now help coordinate and plan the material for numerous outreach events at [named firm] in Bristol. These events (4–5 have run so far) have involved groups of 10–15 pupils of various ages."

"I am able to apply for a certain amount of company time I can spend doing outreach. This year I am allowed to spend 9 h carrying out outreach on company time."

Interestingly, among the teachers there was still evidence of outreach going on with secondary school teachers engaging with their local primary schools.

"We still reach out to local state Primary schools, offering technical expertise, lecture demo's and enrichment days and activities. Some of these are school campus-based others are off campus. For example, Forensic Science Day (5 × 90 YS pupils) and lecture demos (4 × 100 pupils and parents)."

Question: "If You Have Any Further Comments on the Impact of the Outreach Programme on You and Your Career, Please Note Them Here (Positive or Negative)"

Of those responders that gave responses in this category, most simply expressed gratitude for being given the opportunities and associated experiences for being engaged in the outreach program. There were no negative comments. Several mentioned that outreach allowed a break from their research and provided the opportunity to meet other Ph.D. students from different research groups. Bristol's School of Chemistry can have around 250 Ph.D. students at any one time spread across several research groups and 4 years of entry. That coupled with the

influx of students from across the world does mean that not all postgraduates know each other.

Quote. *"Outreach was a highly rewarding experience and helped me to develop additional skills and give me confidence in situations that would not occur during typical PhD study. At the same time, it was typically lots of fun, and a pleasant break from the everyday work and study of a PhD student. I also got to know a lot of students and staff members from different parts of the School of Chemistry who I may not have met otherwise."*

Johnson et al.¹⁹ surveyed physicists and biologists from elite research universities in the United States and noted that there was reluctance to engage in outreach. Their study suggests that physicists view outreach as "outside of the scientific role" and a "possible threat to reputation", while biologists assign greater value to outreach, but their perceptions of the public inhibit commitment. Outreach programs such as the one described will help to overcome these perceptions, and indeed, those researchers who have gone onto academic positions recognize and actively support outreach programs. Indeed, Stofer and Wolfe⁴⁸ conducted a study to understand how exemplary outreach can be undertaken by leading research teams and noted that the major barriers reported by faculties engaged included a lack of professional development for outreach, time, money, and work of this kind being valued. Therefore, outreach training is vital at the Ph.D. level as part of the training of leading researchers of the future. Pratt and Yezierski¹² emphasized the need to have formal training before undertaking outreach for several reasons, not least to build confidence in the researcher and to help them to understand and appreciate the requirements of the audience; very few people can naturally connect with an audience. As noted, the researchers in this program that were surveyed had been involved for over 3 years, and in this way, they had time to develop their skills, working with the outreach leads but also with fellow researchers.

All researchers who were surveyed reported how much they enjoyed outreach. Although not explicitly noted in their surveys, the purpose of each activity was to engage with the audience, impart knowledge, concepts, and skills where appropriate, but foremost to impart a love of and enthusiasm for the subject. This mind set has supported the impact on the researchers reported, but the program avoided any notion that recruitment of students was a goal. Sadler et al.⁴⁹ noted that university-led outreach programs often find themselves being judged on recruitment, which can detract from engagement that is appropriate to the audience. Recruitment will be a natural consequence of a good outreach program.⁵⁰

Limitations

We limited the study to those who had been involved in outreach for over 3 years; in this way, researchers would have had the opportunity to experience several aspects of outreach and develop their skills. Although we do not anticipate a dramatic change in response, we do anticipate that the richness and depth of responses would be less if we included a wider cohort. We were limited by the contact details that were active, but although a wider study would be welcomed, we suspect that most of the core themes have emerged. Respondents may feel that they cannot say anything negative in response to the request for information. Although there is no way to refute this possibility, throughout the outreach program, researchers have been encouraged to share good and bad experiences and to help

shape and improve the events and activities. Therefore, it would be unusual for this cohort to not voice any negative aspects.

Through general surveys and end of year events associated with the program over the years, the main barrier and bad experience for those participating involved interactions with supervisors. In this program we have emphasized to Ph.D. supervisors that they must opt into the program, i.e., agree to their Ph.D. students taking part. Initially, some Ph.D. supervisors decided to veto any students from their research group from taking part, and as a result, any students from those groups were prevented from taking part. As the program emerged and the benefits alluded to here were becoming clear, all supervisors agreed to their students participating. However, relationships between the student and the supervisor concerning participation were not always harmonious. In most cases, supervisors believed that the student did not have time to take part in any activity outside of their research at a particular time; this was left to the student and supervisor to determine, and from time to time, some students were prohibited from taking part, at their supervisor's request. Negative experiences of the program were rare and involved either a failure of equipment or missing resources. When working with school students, their teachers were always present and the Ph.D. students in the program had been trained to leave resolution of bad or inappropriate behavior of students to their teachers. A very strict health and safety protocol was in operation, and so dangerous behavior led to instant expulsion from the activity (very rare).

CONCLUSIONS/SUMMARY

Unusual for a conclusion to a paper, the following quote sums up the impacts of chemistry postgraduates being heavily involved in outreach:

"After my PhD, I gained a place on a highly competitive graduate scheme, which I wholeheartedly do not think I would have gotten onto if I hadn't been involved with the various outreach events during my time in Bristol uni. On a very literal level, the activities and skills acquired looked great on my CV, however it is more than that. Being exposed to ever changing situations, dealing with unforeseen circumstances, interacting with a variety of students and teachers as well as a lot of public speaking had given me the chance to improve my various "soft skills" to a very good level. Yes, my PhD looks great on paper, and likely would get me an interview for a relevant job, however the skills learned and experiences I had thanks to Outreach, are what has shaped me to perform in the way that I do."

For the benefits discussed, we recommend that university chemistry and other departments should promote the career benefits of outreach to postgraduates, potential employers, and also to internal university audiences. Departments might consider how they might best facilitate such activities in a planned way. Training and continued support in outreach is essential, and as we have observed, after a suitable length of time (we judge to be over 3 years), highly competent outreach practitioners emerge. These graduating Ph.D. students not only have a deep knowledge of their subject area and the requisite skill set associated with that area but can plan activities, analyze risk, consider health and safety, and communicate over a range of levels in both written and oral form and are flexible in their delivery and approach, adopting a two-way dialogue. Therefore, it is not surprising that these additional skills have influenced these student's career paths and enhanced career opportunities. In a future publication we will reflect on the key aspects of the

program and how aspects of it can be reproduced in a variety of types (size, resources, etc.) in chemistry departments worldwide. Funding is a key issue, but building a culture that values social responsibility and the myriad benefits to individuals and communities will be discussed among other topics.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available at <https://pubs.acs.org/doi/10.1021/acs.jchemed.3c00261>.

List of articles written for School Students; copy of questionnaire used in this study (PDF, DOCX)

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Author Contributions

T.G.H. and D.E.S. designed the questionnaire and the study. All authors contributed to the text and comments on the analysis of the results.

Notes

The authors declare no competing financial interest.

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