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Article

ChemDiverse: A Chemistry Careers Activity Showcasing Diversity

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ABSTRACT: Women, ethnic minority, and less affluent groups are widely underrepresented in chemistry, a problem that is observed at all levels but begins before college matriculation takes place. The importance of representation and humanization of scientists is crucial. Despite limited progress over recent decades, poor visibility of role models from underrepresented groups remains problematic, emphasizing the importance of initiatives to positively introduce them in classroom settings. Through profiles of underrepresented "success stories" from academia and industry, the ChemDiverse project was developed to encourage underrepresented groups to pursue the chemical sciences at higher education levels by providing teachers with an easy and structured way of encouraging Scottish high school students into science, technology, engineering, and mathematics (STEM). Based on survey feedback from teachers at participating schools, it is a well-formulated project that is easy to implement within the context of the Scottish Curriculum for Excellence.

KEYWORDS: *High School, Outreach, Minorities in Chemistry, Student/Career Counseling, Women in Chemistry*

INTRODUCTION

Research shows that women and individuals identifying as part of a minority group are underrepresented in most science sectors.[1−8] This underrepresentation and the reason for decreasing numbers at more senior career stages have been extensively studied at various levels, from undergraduate studies up to senior scientist and underrepresented faculty roles.[1−3,6,9,10] The Royal Society of Chemistry (RSC) developed a study entitled "The Missing Elements", where it is reported that, in the United Kingdom, 0% of Professors of Chemistry identified as Black or mixed origin, which is a significant drop from the undergraduate level where 4.9% of undergraduate students and 1.4% of postgraduate chemistry students[11] identified as Black. From this study, six key interactive themes are identified as essential for impact retention and progression for the minorities: attraction, inspiration, and progression; mentorship, sponsorship, and network; the culture of chemistry; the funding system and structural barriers; global community and leadership in the community; accountability and allyship.[11] The "leaking pipe line" in science, technology, engineering, and mathematics (STEM), indicating that there are a number of reasons why, for example, women opt out of an academic career, highlights the importance of having a greater diversity, as broadening the recruitment base will help underrepresented individuals feel more included and supported in their working environment, improving retention over time.[12] An alternative theory[13] is described by the "braided river" approach, which acknowledges the benefits to organizations involved in STEM of partnerships with nonscientific experts and industries. This approach also advocates elevating the value placed on STEM skills across a wide range of professions. Various initiatives have been launched at different levels, from primary[14] and high schools[6,14,15] to universities,[10] to inspire underrepresented groups and show the importance of continuing into these type of career paths, but there is still much to be done to be able to encourage more students from a wider variety of backgrounds.[2−5] Even simple interventions such as adapting presentation slides to include full names and photos of scientists, in addition to traditional citations, can make a significant difference to the experience of students from minority groups.[16] It has also been determined that inclusion of diverse perspectives is fundamental to giving a sense of belonging to underrepresented groups.[4] Previous studies have shown the importance of having mentors matched by gender and ethnicity to increase mentorship experience.[2,6,10] More than two-thirds of participants from a diverse group, 96% of whom identified as an ethnic minority, had a role model of the same gender or ethnicity, while 56% believed that media exposure to gender and ethnicity matched STEM professionals would be effective in encouraging underrepresented groups to continue with STEM careers.[6] An alternative approach is modeled by the "Diversity in Chemistry" Web site, which provides online resources to use in classrooms showcasing diverse scientists. Such approaches have

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shown that incorporation of more diverse representations of scientists in the classroom has a positive effect across the student curriculum.[2]

In universities, the effect of the leaking pipeline is observed from early undergraduate studies.[11] Higher Education Statistics Agency (HESA) statistics[12] indicate that more men than women are attracted to study the Physical Sciences. These numbers show the importance of encouraging those from underrepresented backgrounds at the earliest opportunity. Indeed, women, people from Black and ethnic minorities, and LGBTQIA+ are underrepresented at senior levels in industry and academia.[6]

The Aspires Report[17] outlines the importance of developing interest in science at the primary level. Enhancing the representation of minority groups in science should also begin at this stage of a student's education to ensure engagement and success.[1,5,18] Informing pupils of the importance of the role that chemists have played in many advances that enhance modern life is key to encouraging them to consider a career in the Chemical Sciences.[5,18] Indeed, in Scotland, this is recognized through inclusion of several relevant science curriculum criteria, or "Experiences and Outcomes" prescribed in Education Scotland's Curriculum for Excellence documentation, specifically:

- Through research and discussion, I have an appreciation of the contribution that individuals are making to scientific discovery and invention and the impact this has made on society. SCN 2-20a
- I have collaborated with others to find and present information on how scientists from Scotland and beyond have contributed to innovative research and development. SCN 3-20a
- I have researched new developments in science and can explain how their current or future applications might impact on modern life. SCN 4-20a[13]

Herein, the ChemDiverse project, which focused on showcasing chemists from underrepresented groups to high school pupils to increase their understanding of, and aspiration toward, careers in chemistry, is presented. By presenting "success story" profiles of chemists from underrepresented groups currently working in academia and industry, it aimed to present positive role models for high school students who often do not see themselves represented in these roles. We see this approach as aligned with that of the previously discussed literature, specifically around developing a sense of belonging, and also aligned to the theme of "attraction, inspiration, and progression" within the RSC's "The Missing Elements" report.[11] A series of nine career profiles were codeveloped with practicing chemists from a range of underrepresented groups, and working with Scottish teachers, across different local authorities and geographical regions, these profiles were incorporated into their classrooms on a weekly basis. This work presents the design and implementation of the ChemDiverse project and evaluates its effectiveness through a survey of participating teachers. A follow-up study will present the effects of students' participation in the ChemDiverse project on their self-efficacy and career attitudes.

■ POSITIONALITY STATEMENTS

The lead authors were primarily responsible for the design, implementation, and management of the ChemDiverse project, and therefore, their positionality is important to consider and is provided below.

F.J.S. is a straight, white male and is the first in his family to go to University. He is a former Secondary School Chemistry Teacher and currently a Senior Lecturer in Chemistry with research interests that span anti-infective drug discovery, numeracy in STEM education, and STEM careers education. At the time of conducting this research, S.T.R.V. was a PhD student and part time research assistant. She is currently a postdoctoral researcher working in sustainable materials. Further details are included in the representative case study shown in the Supporting Information. D.W. is a straight, white female and started her career more than 40 years ago as a chemistry technician. She has worked in higher education in a variety of roles since the 1970s.

■ PROJECT DESIGN

Desired Outcomes

- Provide students, and their teachers, with opportunities to learn about the wide range of careers in the Chemical Sciences and the diversity of individuals employed in these careers.
- Provide teachers with an easy-to-implement chemistry career activity they can engage with over an extended period.
- Provide teachers with an activity that contains chemistry career information that would otherwise be challenging for them to develop themselves.

Implementation

The Department of Pure and Applied Chemistry's network of external industry contacts, alumni, and internal staff were used to advertise for individuals who identified as belonging to an underrepresented group and were engaged in chemistry as their career. A total of nine career profiles were cocreated with these individuals, as described more fully in the Profiles subsection below. In parallel with the work to create the career profiles, a database of email addresses for schools in Scotland was compiled using publicly available information from school/local authority Web sites to circulate an invitation to participate in the ChemDiverse project. In the authors' experience, these email addresses can often be incorrect, may not be regularly monitored, or do not allow for information to easily get to the target recipient (in this case, the teachers in the Science department). Therefore, we also used an internal database of chemistry teacher email addresses who have participated in chemistry outreach activities at the University of Strathclyde and a Scotland-wide email list for teachers of Chemistry called Strontium.

We sought to recruit teachers engaged with S3 (aged 14/15 at the end of the school year) chemistry classes into the project. There were several reasons for targeting this year group: (i) S3 students do not have end of year examinations, or external qualifications, giving teachers more freedom over incorporating activities likely to be perceived as "extra-curricular", such as this project; (ii) the students will have some interest in chemistry as they will have chosen that subject to study, which should provide some additional engagement with the project; (iii) in later year groups, pupils may have already "dropped" chemistry as a subject from their timetable, as this is when the curriculum starts to "narrow" in Scottish schools. One could construct an argument based on (ii) and (iii) that an even earlier year group would be appropriate, but as our project was focused on chemistry careers and S3 is the year group that first chooses

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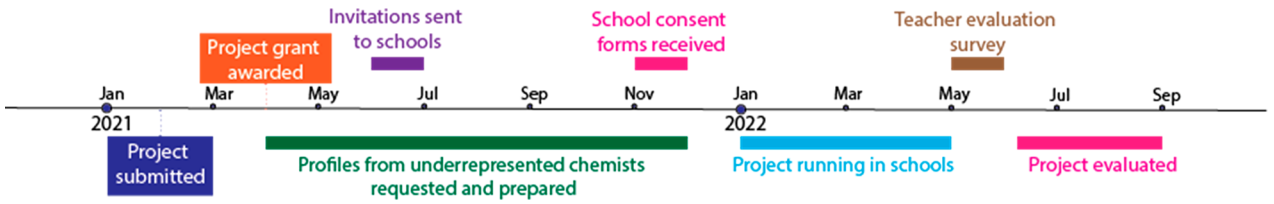

Figure 1. Project implementation timeline throughout 2021 and 2022.

Figure 2. Example of a career profile used at the schools for the ChemDiverse project.

individual science subjects, this was deemed to be most appropriate.

Participating school teachers were provided with nine career profiles intended to be used on a weekly basis as part of their normal teaching practice. The guidance provided to teachers suggested that one profile per week could be used as part of a 10−15 min activity involving the students first reading the profiles, then answering a set of reflective questions (see Supporting Information), and finally engaging in a closing class-wide discussion. However, we encouraged teachers to use the career profiles in a way that suited them best, so long as they were engaged weekly (allowing for holidays or other necessary interruptions). After the students' engagement with the career profiles, teachers were asked to complete an evaluation survey, data collected in May 2022. During the months of June−August 2022, an initial evaluation of the project was completed. A summary timeline of the implementation of the ChemDiverse project is shown in Figure 1.

Profiles

Nine profiles were cocreated with participating chemists (see Figure 2 and doi.org/10.15129/c8d9c6b7-e62f-4aba-806f-ef0c4f42495f). The process began with the project team agreeing on a list of broad questions that participants should answer, covering details of their school to career transition and also reflecting on the interaction between their career and the underrepresented group to which they belong. The questions also covered their interest in chemistry, current job, and what they most enjoy about working in the chemical sciences. Many of the profiles provided technical details, some of which were at a high level, of the participating chemists' research, which were unlikely to be directly understood by the students. However, these were kept to allow for discussion between students and teachers about science and to potentially relate the work to societal importance. The full set of questions used to construct the profiles can be accessed via the University of Strathclyde's data repository, doi.org/10.15129/c8d9c6b7-e62f-4aba-806f-ef0c4f42495f.

In order to recruit individuals to complete the profile questions, the project team sent email invites throughout their own personal networks, the University's alumni network, and through the Royal Society of Chemistry membership. The project team then iteratively curated and edited the responses to the questions in partnership with the participating chemists to construct the final career profiles. During this process, the profiles were shared with several practicing high school chemistry teachers to check for accessibility for the target S3 audience, and consequently, further refinements were made.

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Table 1. Summary of the Diversity Represented within the Profiles

Individual	Challenges Faced	Example Quote from Profile
Aaron Lau	Minority Background	I have wondered if remarks I got from students was because of my minority status or my 'foreign' accent. Also, because I did not "grow up" in the UK university system, I had to learn the norms and expectations.
Ferial Haque	Minority Background, Woman	Being a war survivor and a migrant woman of color in the seventies did not help matters as jobs in chemistry were scarce. During the 1970s it was not common to see women in science in any country that I have pursued studies in. So, it was a solitary working life.
Ashleigh Fletcher	Disabled; Woman	I think it would be fair to say that I have suffered from gender bias during my career progression, particularly prior to my current position where opportunities and support offered to male colleagues were not provided to me.
Michael Brown	Mental Health	I struggled a lot halfway through high school with mental health issues, which was making learning difficult due to lacking energy most days. However, I managed to overcome this with support from friends, and a lucky realization of my own poor mental health.
Laura Faulds	LGBTQIA+; Woman; Low Socio-economic Background	I come from a part of Glasgow that has quite a high poverty rate and throughout school I was openly discouraged from going to university due to not many people achieving the required grades. Career advisors were always pushing for us to look into apprenticeships etc. and not follow the higher education path.
Iain McLellan	LGBTQIA+; Low Socio-economic Background	Fortunately, since leaving school, I have never faced homophobia in any of the jobs I have had and for that I am extremely grateful.
Sara Velasquez	Woman, from Underdeveloped Country	I think the biggest challenge I have faced has always been finding a way to get here. It was very difficult mostly because of the country I was born in.
Christine Davidson	Woman	A more insidious challenge is the fact that women in academia disproportionately deal with pastoral care and academic administration issues, making it harder to build a research career.
Saime Salehjee	Ethnic Minority Background; Woman	At some point, I realized I was trying to fit into educational and professional settings where I visibly looked or felt different. But later, I realized that I do not need to 'fit in'; instead, my unique identity, visible and invisible, will support the workplace and equally help me progress professionally.

Not all profiles contained the exact same questions, as each profile was individualized in order to convey the most salient features of the participating chemists' career journey, which was carried out in collaboration with each individual. Notable features of the profiles included images and a brief description of the participating chemists, including their underrepresented group, at the top of the profile.

Through these profiles the most underrepresented groups in the chemical sciences were showcased, from underrepresented international individuals to those from low socioeconomic backgrounds to first females in specific roles and representatives from the LGBTQIA+ community. The profiles include: a senior lecturer who describes how he is one of the few in his position with Chinese heritage; a scientist freelancer describes how she faces her daily work after being a war survivor and a migrant woman of color; a deputy head of department who has battled a degenerative inherited condition while working in a male gender oriented discipline; a senior assistant scientist who decided to follow a career in chemistry despite not studying this subject at school and struggled with mental health issues during his high school years; another senior assistant scientist one comes from a low socioeconomic background and was discouraged from going to university; a LGBTQIA+ senior lecturer who faced challenges growing up in Scotland as a gay man; a PhD student who has traveled the world and faced language and cultural barriers to pursue her study goals; a Reader who was the first female lecturer to be appointed; a lecturer who is the only Muslim and South Asian woman in her immediate working environment. Since a diverse array of chemists from underrepresented groups had been assembled, it was expected that the profile collection would appeal and inspire a broad student population (Table 1).

RESULTS AND DISCUSSION

Participation

This project was focused on Scottish schools. 380 schools were contacted, of which 42 initially responded positively and 18 of those chose to engage in the project, to receive the career profile package. The level of participation for this project was significantly lower than those in previous studies.[5] The lower level of participation is probably because of the COVID lockdowns, after which schools and teachers have not been so willing to engage in activities that are not discipline specific projects despite being part of the general education curriculum. It was pleasing to note that 56% of the schools that engaged in this project are Schools for Higher Education Programme (SHEP) schools and included one Aspire North, three FOCUS West, four LEAPS, and two LIFT Off schools. The SHEP program is a national program to help schools where few pupils go into higher education and is funded by the Scottish Funding Council (SFC). The program supports the Senior Phase of Curriculum for Excellence, focused on S3 to S6. The program covers four regions:

- North program (Aspire North)
- Fife and Tayside program (LIFT Off)
- South East program (LEAPS)
- West program (FOCUS West)

Teacher's Evaluation Survey

As a preliminary means of evaluating the effectiveness of the activity and noting our desire for ease of use for teachers, we requested that participating teachers complete an evaluation survey (Supporting Information). In this survey, 5 out of the 18 teachers participated. This response rate may not seem high, but in comparison to other outreach projects, the authors' have facilitated in this context, it is higher than others.[19] This showed that, despite the low level of school participation, those who participated were engaged in the activity.

According to the surveyed chemistry teachers, the design of this project was easy to implement into their teaching practice, with 80% (4/5) responding positively, probably because the project was developed based on previous experience of designing outreach programs. 60% of the teachers (3/5) considered the ChemDiverse resources relevant or very relevant to their local school career-related curriculum, with the remaining 40% (2/5) saying it only had some relevance. These results could indicate that only certain teachers consider it important to teach career education as a part of their curriculum. Most teachers 80% (4/5) believed it would have been difficult to source this type of resource on their own, with the remaining 20% (1/5) stating it would be of moderate difficulty. Given that usually high school teachers have no or limited contact with universities, the importance of these types of activities was acknowledged. 60% (3/5) of the teachers found the activity to

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be engaging, 20% (1/5) moderately engaging, and the final 20% (1/5) somewhat engaging. Based on the profiles and the resource pack, it was shown that, despite more than half of the teachers finding it engaging, sometimes it is important to modify the activity depending on the school and the number of diverse students in the class group.

The initial guidance given to teachers regarding participation in the ChemDiverse project suggested a 10 min activity involving reading the profiles and answering questions on the career profile reflection document, once a week. However, as part of the evaluation survey, we asked in what way teachers incorporated the activity into their classes in case they chose to deviate from the guidance. Some teachers used a few profiles at a time; others kept to the suggested one per week. Some teachers used this activity as their regular "lesson starter" for their class. Some teachers allowed the students to read the profiles themselves, and others read them out to the entire class. One teacher augmented the activity by spending more time on the reflection phase, getting students to independently answer the questions, then discussing with a partner, and finally sharing with the class via writing on a whiteboard. While most teachers commented that they did have to adjust the suggested guidance, they were still able to use their own expertise in their classroom, and knowledge of their students, to adapt the resources such that there was a positive benefit for the students. The diversity of approaches used by the teachers speaks to the flexibility of the resources and their ease of use.

The final part of the survey asked teachers to describe any positive and negative experiences that their students had while participating in the project. All teachers reported that their students had positive experiences relating to issues of diversity, specifically mentioning the benefits of discussing barriers or underrepresentation. For example:

"Pupils enjoyed seeing diverse backgrounds of the profile members." − Teacher 3

"It was really nice to see pupils engage in discussions and speak about 'no wrong path'. Pupils enjoyed seeing that it is not all about being academic and that there is a wide range of jobs out there." − Teacher 5

It was also pleasing to see that LGBTQ+ students were encouraged to see LGBTQ+ scientists:

"Any LGBTQ+ scientists were great for some of our LGBTQ + pupils. I could see them perk up." − Teacher 2

This observation highlights the importance of enhancing representation of traditionally underrepresented groups, particularly for those with unseen identities, as in this case.

Pupils also appreciated that worldwide travel is a common feature of a working scientist. The pupils were very interested to hear about the qualifications that can be achieved and the difficulties that were overcome to allow the scientists to achieve their ambitions. The pupils enjoyed knowing that there is no wrong path.

One teacher noted that the pupils that are doing well in chemistry seem to have been more engaged with the project, and this may have been linked to another teacher's observation that

"Some pupils found the profiles long and struggled with the language." − Teacher 3

Indeed, another teacher made a similar comment:

"The content of the profiles was more suited to older pupils. They required interpreting for the S3 level in terms of the qualifications the people had achieved and understanding what their job involved. A lot of their research was difficult to explain to this age group." − Teacher 4

We acknowledge that career paths, including the qualifications and research details, may be difficult for a student to understand directly from a profile, but as intended, this can be understood through discussions with a teacher. Indeed, this seems to have happened in this teacher's case, as they explained that they interpreted the information for their class. The comments of literacy and complexity being too high for the target S3 audience were made despite the task being checked by practicing teachers prior to use. This likely points to the individual differences that can be found in different schools with different student demographics. Nonetheless, all the teachers provided positive comments about the project and were able to adapt the resources to the needs of their own classes such that they obtained a positive outcome.

LIMITATIONS AND IMPLICATIONS

The ChemDiverse project was designed and implemented in Scotland, specifically linked to the Scottish Curriculum for Excellence. Therefore, it may not be directly relevant in other contexts or may require modification to achieve relevance. However, a detailed account of the design and implementation provided herein should easily allow such modifications. It should be noted that direct relevance to the intended educational context, for example, by aligning with available curriculum documentation, is likely to positively affect the response and engagement from teachers and schools.

Delivering a project such as ChemDiverse is reliant on leading institutions and project leaders having access to satisfactory networks of volunteer chemists (for profiles) and schools. For this work on the ChemDiverse project, it was necessary to extensively utilize a variety of mechanisms to obtain volunteer chemists in sufficient numbers and diversity. Therefore, they could be difficult to replicate without established networks. Alumni connections through official or personal networks are an important resource to consider. Successful implementation of this project is also reliant on having good school networks. This was not necessarily a limitation within our project, as the Department of Pure and Applied Chemistry at the University of Strathclyde has extensive reach to schools throughout Scotland, but it could be a concern for others to replicate. However, there are many charitable bodies that can help with this; for example, in our region, we have access to the STEM Ambassadors network and the Royal Society of Chemistry team of education coordinators, both with established school networks.

It is reflected in the evaluation section that, although the participation rates and completion of evaluations appear low for the ChemDiverse project, these are actually relatively good based on our extensive past outreach work. Participation, and especially evaluation, rates are local context and sociopolitical environment dependent. For example, in our region, while this project was carried out, there was a strong narrative around unreasonably high teacher workload, and indeed, teacher strikes, which significantly impacts a school's ability to engage with outreach activities such as the one presented herein. This is often unavoidable, but considerations such as alignment to the curriculum may help. Additionally, we note that allowing the project to be flexible, as reflected in our project, may also enable teachers to continue to engage when they otherwise would not.

The effort required to design, implement, and manage a project such as ChemDiverse is not insubstantial and may not be possible within the workloads of those interested in doing so. We note that the ChemDiverse project was funded by external funds to our institution through the Royal Society of Chemistry (RSC)

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Outreach fund. This enabled two student interns and a research assistant to provide administrative support and data analysis support, respectively, lowering the effort barrier and increasing the perceived impact of the project to our institution.

CONCLUSION

We have developed a set of career profiles of diverse chemists that have been used in several Scottish schools. The project has served as a positive start for inspiring high school students to seek a career in higher education STEM, more specifically Chemistry. The resources developed as part of this project could be used and adapted by school teachers in the coming years. It is our intention to continue to cocreate more career profiles to make a "profile library" from which teachers could choose the most appropriate ones depending on their specific classes, considering their composition. The teacher's feedback has been fundamental to understand what works well and what needs to be improved so that changes can be made for further iterations of the project. As alluded to earlier, we are also conducting a more thorough evaluation of the impact of participation in this project for students, which will be disseminated in a future publication. Furthermore, we are keen to explore the possibility of developing video profiles, rather than "paper" profiles, to reduce the reading burden that may greatly affect some groups of students.

ASSOCIATED CONTENT

Data Availability Statement

The career profile questions, career profiles, and class room reflection activity are available from the University of Strathclyde data repository, doi.org/10.15129/c8d9c6b7-e62f-4aba-806f-ef0c4f42495f.

Supporting Information

The Supporting Information is available at https://pubs.acs.org/doi/10.1021/acs.jchemed.3c00355.

SI1 Teacher Evaluation Survey (PDF; DOCX)

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Notes

The authors declare no competing financial interest.

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