A Resource to Support Decolonization of the Undergraduate Chemistry Curriculum

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Abstract

In our taught chemistry curricula, the majority of individuals who are used to illustrate historical aspects of chemistry topics are white western chemists. Decolonizing the undergraduate chemistry curricula is increasingly recognized as an important step towards developing a more inclusive higher-education environment for students from minoritized ethnic backgrounds. Here, we provide the first openly accessible resource that can be used to decolonize an undergraduate chemistry course. In particular, the resource provides examples of both individual scientists and groups that can be used to illustrate chemistry teaching, and hence provide role model examples of scientists from different cultures. The resource presented provides a significant body of examples for chemistry lecturers to use as they begin working towards decolonizing their curricula.

Key words: Decolonization, Curriculum, Chemistry, Ethnic Minority, Undergraduates

Introduction

Minority ethnic individuals are significantly under-represented within the chemistry researcher population and broader commercial chemical workforce,[1-4] providing an urgent issue for us to address as a chemistry community. As early as the 1970's, a survey by Hernan Young in the Journal of Chemical Education revealed the extremely low proportion of ethnic minoritized scientists in the United States.[5] More recently in the UK, analysis of the longitudinal British Cohort Study identified that people from white ethnic backgrounds were about 1.5 times more likely to have worked in the sciences than those from minority ethnic groups.[6] Despite awareness of under-representation of minoritized individuals in the sciences and "calls-to-action" over many decades, it is still an issue of critical importance today.[7-11]

A recent report on progression trends for ethnic minority students highlighted a sharp decrease in the number of students from this group who migrate from undergraduate to PhD level.[12] The reasons for this are not completely understood but a significant proportion of minoritized ethnic students report that they are not having a positive experience in higher education.[13-15] For example, there is a significant and widespread attainment gap between the number of high-quality degrees awarded to UK-domiciled white students compared to UK-domiciled students from ethnic minority groups.[12,16,17] A high proportion of black UK students say that the curriculum does not reflect issues of diversity, equality and discrimination,[15] and that they therefore do not feel a "sense of belonging." Moreover, an interview study done by Helen Egan *et al.* in 2021 on the experiences of social science students from a Black, Asian, and Minority Ethnic (BAME) backgrounds who dropped out of university education categorically identifies problems with social integration as one the major issues that needs to be addressed to improve retention of this group.[18]

Over the last two decades, the inclusion of role models in teaching and learning materials has been acknowledged to be important in encouraging women to pursue careers in STEM.[19] There is now growing evidence that inclusion of role models in teaching material similarly improves the academic retainment, progression, and achievement of ethnic minority students. [20,21] Role model inclusion promotes levels of positive engagement with the subject area as well as highlighting potential career pathways.[19,22] Encountering realistic and relatable role models has also been noted to contribute strongly to increased self-efficacy and positive self-identity

for pursuing and persisting in STEM.[23,24] The lack of diversity and inclusivity of appropriate role models across the educational environment is therefore strongly implicated in producing negative impacts for the overall attainment of ethnic minority students.[25,26]

In 2019, Universities UK published a report on closing the attainment gap for higher education undergraduate degrees which recommended that increased efforts be made to support minority ethnic individuals, including decolonizing the curriculum.[27] This provided an impetus for academic departments to decolonize their curricula, as a part of work that they should conduct to address racial inequalities in university attainment. The report importantly noted that where decolonization is carried out as part of broader work to 'diversify' course content (usually by considering other aspects of diversity such as gender, disability, and sexuality), it is important to ensure that this does not result in a loss of focus on the issue of race.

These considerations have led us to develop an open resource that provides a repository of role models (individual and groups) that can be used in teaching Chemistry, primarily at the college/university level. We highlight biographical profiles from different ethnic backgrounds and cultural groups, with chemical examples included from across the various chemical sub disciplines. The examples we provide here are mainly from Africa, Ancient China, Ancient India, the Medieval Middle East, along with a selection of work from prominent Black scientists in the West in the early 20th Century. We have catalogued the examples in several ways for ease of use. By sharing these examples, we aim to provide a resource that can contribute to addressing racial inequalities that currently exist in university chemistry education. The work presented here contributes to our wider efforts to decolonize and diversify the curriculum of the Chemistry Department of the University of York, UK.[28]

We note that there have been a small number of other recent publications reporting activities to introduce aspects of Diversity, Equity and Inclusion (DEI) into chemistry teaching. For example a student conference activity employing active learning,[29] foundational and extracurricular DEI activities, the creation of alumni profiles,[24] and the development of a "Not all Chemists are white men poster" and slide-show resource.[30] Pence and Pence have collated a number of sources of biographical information and present a "Profiles in Chemistry" virtual activity involving eight videos of women scientists and people of color.[31] Ries and Mensinger have created a "Diversity in Chemistry" web-based resource to support the inclusion of more diverse Chemists for example at the start of a lecture.[3] The resource we present here complements these other activities, by focusing for the first time on presenting a repository of

examples to decolonize a chemistry curriculum. Our work also provides a wider number of examples than were included in these previous publications.

Methodologies:

Curation of Resources

Initial work began with a manual search through the 'History of Science, Technology and Medicine in Non-Western Cultures,[32] to identify Chemists and Scientists who were instrumental in the development of materials and techniques in chemistry and closely related fields. This, along with previously collated examples gathered in the Department of Chemistry at York, UK,[28] formed the foundation of the resources.

To expand on the initial work, targeted keyword/string searches were performed in a variety of search engines. These keywords/strings included '*History of Middle Eastern Chemistry', 'History of science in China' 'Significant contributors to science in India'* as well as further research on general subject areas mentioned in the encyclopaedia of chemical relevance, such as fireworks. Examples were identified, collated and categorized. The type of material we have acquired to date is summarised below:

- Compilation of a set of examples highlighting the work of Black chemists, contributions from Africa, Ancient China, India, and the Arab world, to provide further examples for incorporating in lecture material.
- Links to related resources featuring ethnic minority chemists, including magazine articles, blogs and social media posts (For example, items created for Black History Month).
- Fact finding and gathering (e.g. reports by professional bodies, newspaper reports, university web sites, etc) of best practice on what decolonising a curriculum means for a science department and why it is important.
- Compilation of references from the published literature, conference abstracts, and web links on decolonising the science curriculum.

Access to Resources

A core principle of this work is that the sources/references listed in the resources gathered are widely available and accessible. Whilst we appreciate that primary sources are preferable as scholarly publications, the focus of our research was on text, articles and websites that are freely available to all educators, particularly those who do not have the logistical, or financial resources to access the primary sources. Where resources are not easily accessible, this is clearly noted and the easiest approach to access them has been clearly stated.

Project Outputs

The Resources

All the resources outlined in the methodology can be found in the Supporting Information. The resources are arranged under three broad sections which are discussed in more detail below.

Section 1: Tabulated Contributions of Chemists from the Medieval Middle East, Ancient Africa, and Ancient Asia

In this section, 84 different contributions to the development of chemistry from the Medieval Middle East, Ancient Africa, and Ancient Asia were compiled under the sub-disciplines of chemistry where they might be included as examples, e.g. organic, inorganic, physical and medicinal chemistry. An extract from one of the Tables (Table S1a (ii)) is shown in Figure 1. The web-links contained in the references are provided to enable educators to access some of the earliest examples of chemistry developed outside of the West. To highlight one example, a great deal of current chemistry laboratory techniques were developed by early Arab Chemists.

Organic Chemistry

Date/period (if known)	Chemical / Chemistry	Sources
1000 BC	Natural dyeing chemicals and tanning of leather.	1. The Colours of Nature. https://thecoloursofnature.com/natural-dyes/a-brief-history/ (accessed August 23 2022). 2. McAwley, J. https://slightlyblue.com/culture/all-you-need-to-know-about-the-history-of-indigo-dyeing/ (accessed August 23 2022).
1500 BC-1000 BC (Verdic age)	First to design retorts used to control the distillation of zinc.	1. Wikipedia. https://en.wikipedia.org/wiki/Zinc_smelting (accessed August 23 2022).

Figure 1. An extract from the resource highlighting contributions to organic chemistry from Ancient China, showing the time period, sub discipline of chemistry and reference sources.

A quantitative graphical representation of the 84 different examples which include chemical apparatus, experiments, and laws, that originated from the Medieval Middle East, Ancient Africa, and Ancient Asia are displayed in the schematic illustration presented in Figure 2.

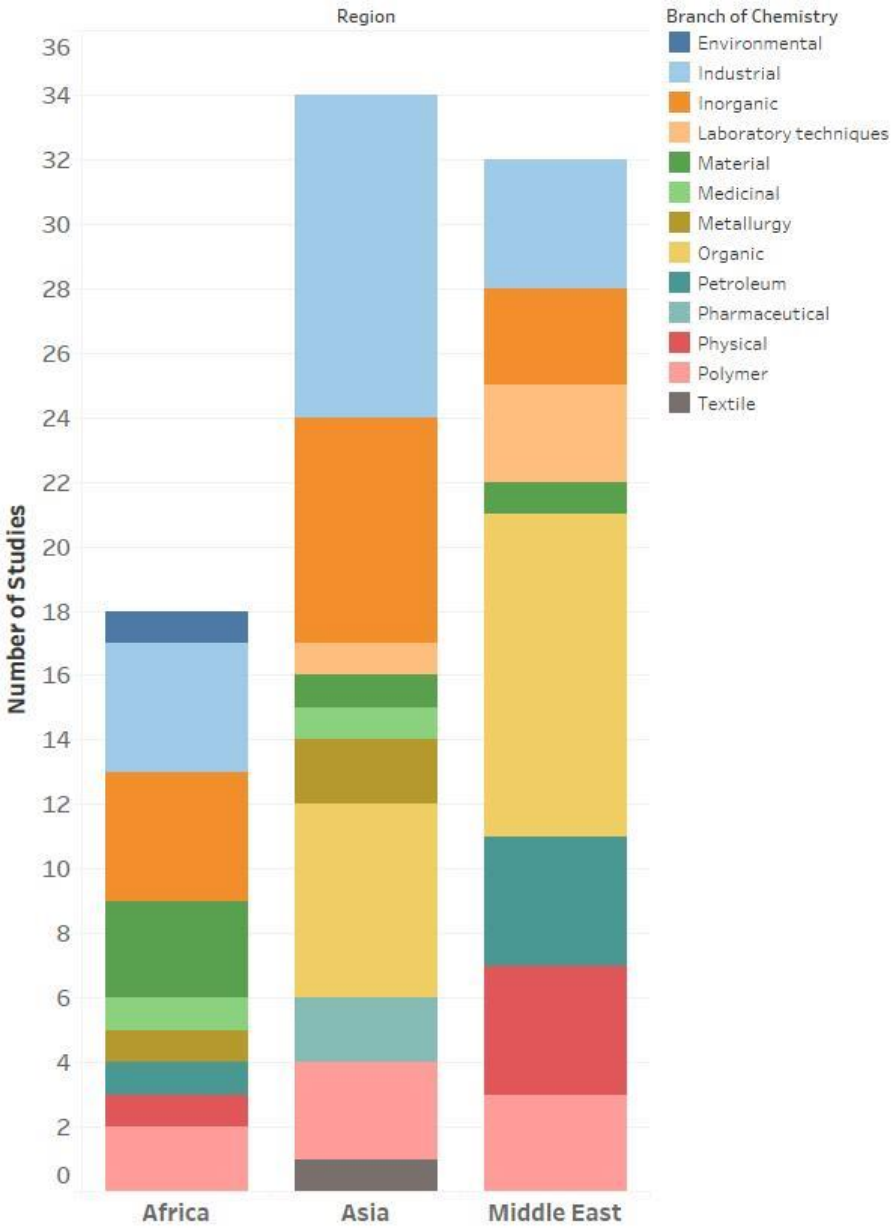

Figure 2. Bar chart showing the number of studies from the Medieval Middle East, Ancient Asia and Ancient Africa. The colours indicate the different branches of chemistry covered by each study collected in Section S1 of the resource.

Figure 3 provides a further, schematic illustration of the diversity of the material collected in Section S1 of the resource, showing the spread of dates of the examples, indexed by geographical location.

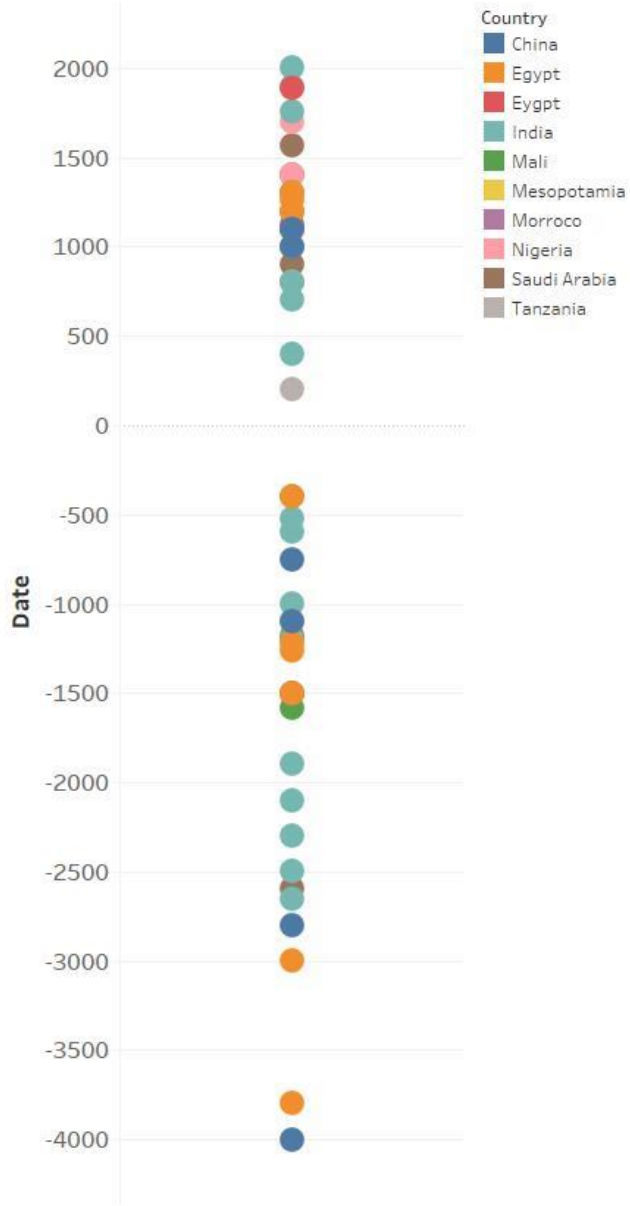

Figure 3. Schematic diagram the dates (from 4000 BC to 2000 AD) of the examples that are included in Section S1 of the resource. The colours indicate the geographic location where the studies were conducted.

Section 2: Short Biographies of Black American and Asian Chemists including Their Contributions to Chemistry

This section of the resources contains short biographical profiles of 24 black American and Asian chemists, including a summary of the notable chemistry they performed, organised into sub-disciplines of chemistry. Keywords have been added to facilitate searching and clarifying links to related areas of chemistry. References are included with each biography, with a reference to a picture of the Chemist if one is available. Some of the biographical profiles featured in the resources also contain information on where the chemistry of the individual might be included in the curriculum.

An example of one of the biographies is shown in Figure 4. The web-links contained in the references provides an easy to access starting point for educators to consider a more diverse range of chemists and their contributions, however this is necessarily tensioned against possible changes to these links over time. Examples included are drawn from a wide range of sub-disciplines and areas of chemistry to make the resource as versatile as possible.

Dolphus Edward Milligan (1928-1973)

He was an African American chemist with expertise in spectroscopy. His research focused on using spectroscopy to study reaction intermediates at extremely low temperature. Dolphus work on free radicals and the spectra of molecular ions research earned him many different awards.

Areas of research: spectroscopy, intermediates, free radicals, ions, analytical, kinetics.

1. Wikipedia. https://en.wikipedia.org/wiki/Dolphus_E._Milligan (accessed August 2022).
2. Wisniewska, Z. https://www.blackpast.org/african-american-history/milligan-dolphus-1928-1973/ (accessed August 2022).

Photo: https://nistdigitalarchives.contentdm.oclc.org/digital/collection/p16009coll5/id/491/

Figure 4: A biographical profile from Section S2 of the resource highlighting the contributions and chemistry performed by Dolphus Edward Milligan. Key words indicate the areas where his work may be included in the chemistry curriculum, plus references and a link to a photograph.

Section 3: General Resources

This section includes a range of links to other collated lists and web-resources including lists of contributions of Black, Asian and African female scientists and contributions from the Medieval Islamic world. These resources provide a broader range of examples to facilitate decolonizing topics in the wider science curricula as well as providing some intersectional role models. At the end of the Section S3, we have also included some examples from the educational literature of publications (web and print) where ethnic minority and female

scientists have been introduced into undergraduate chemistry teaching, and also works discussing the principles of decolonization in science subjects.

Discussion

Our intention is that the material contained in all three sections of the resource described above can be used to supplement current teaching activities, and hence facilitate an activity to decolonise a curricula. In particular, the provision of this resource removes practical barriers, such as lack of time,[33] lack of fundamental knowledge on decolonizing a chemistry curriculum, and lack of awareness of examples from ethnic minority scientists and the global south, due to them not being included in lectures or textbooks historically.[34,35] The resource is highly versatile as it provides content across a wide variety of sub-disciplines of chemistry. The material provided can usefully be employed to connect to themes such as "the diverse histories of chemistry and science", and "role model scientists from different backgrounds and cultures" as part of the strategic approach described in Reference 28.[28] The resource can also be used in a pragmatic manner, to first make small (but meaningful) changes to an area of teaching, monitor feedback, and then gradually further develop new content.[36]

It is important to consider how examples of the contributions of ethnic minority scientists are introduced into teaching materials in a meaningful way. Reis and Mensinger report that biographical information of diverse scientists should connect to the taught content rather than act as stand-alone elements,[3] whilst Gee et al. suggest the use of "Try this" problems to connect with lecture material.[30] A study of student views on decolonization suggests that who is teaching the curriculum, and how it is delivered (e.g. through the use of active learning) are also important considerations.[37]

The resource provided offers a starting point to support the development of new or refreshed course content and can be used to intiate discussions amongst faculty. Decolonization of the curriculum can be a potentially charged issue, with some individuals expressing concerns about decolonisation having the potential to "erode curriculum quality" or "jeopardise scientific integrity".[35, 38] In the context of chemistry education, we suggest that decolonizing should not be viewed as controversial, as it simply allows educators to update their teaching materials in a way that more accurately reflects the historical and complete contributions from minoritized scientists, thus making the science that we teach more robust.[33] Our experience has been that visible support from senior leadership, an enthusiastic response from our student body, and

regular communication have helped ameliorate concerns and build very broad departmental support.[28]

Although the initial fact-finding stage of the project has been completed, examples will continue to be collated and will be made available via a web-resource which is currently under development. Additional resources, for example a set of PowerPoint slides based on the biographical profiles are also under development. We hope that making the resource openly available will stimulate interest in decolonisation of the chemistry curriculum, empowering educators to easily identify relevant examples and help "lower the activation barrier" to staff to include more diverse role models in their teaching, as well as deliver a fuller global perspective of chemistry for our undergraduates.

Concluding Remarks

It is important to acknowledge that there are a range of factors that should be tackled to ensure that all students feel welcome within higher education environments. A recent article from White et al. reviews the key literature on this issue, highlighting that best-practice should include cultivating relationships, allowing students to make mistakes and the importance of group work.[39] The resource provided here supplements these much needed efforts by providing another means to make students feel welcome. Importantly, it provides the first openly available resource for chemistry lecturers to use as they begin working towards decolonizing their curricula. We share the resource being very much aware that it can be significantly expanded, and hope that by presenting this, others will be motivated to both fund and work on the development of a wider, openly accessible decolonizing chemistry resource. Further, we note that such resources are badly needed for all STEM University-level teaching, as well as for primary and secondary education.

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Supporting Information

The Supporting Information is available at XXX.

Contributions from Ancient Asian, African and Middle Eastern Chemists: Short Biographical Profiles of Asian and Black American Chemists: Other Resources: Further References.

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