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Representations of women and men in popular chemistry textbooks in the United Kingdom and Republic of Ireland

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Textbooks are an important aspect of students' school lives and the representation of scientists in textbooks is a proxy for the representation of who can do science. This study investigated the names of scientists and other people mentioned in four commonly used textbooks in the three education systems in the UK and Republic of Ireland (England, Wales, and Northern Ireland using the A Level system; Scotland using the Curriculum for Excellence Highers system; Republic of Ireland using the Leaving Certificate system) and characterised them by gender. We found an overwhelming bias towards naming of famous men in three of the four textbooks (1 man and 0 women in the A Level textbook; 8 men and 0 women in the first, and 48 men and 2 women in the second Curriculum for Excellence textbooks, and 45 men and 1 woman in the Leaving Certificate). We subsequently analysed images and again found a dominance of images representing men in three of the four textbooks including only 4 women in a total of 68 images in the Leaving Certificate textbook. These images were analysed by role (scientist or not), and by activity according to UNESCO criteria. There was a tendency to show men in scientific and other occupational roles while women were less well represented in scientific roles and were pictured in domestic and buying activities. This work aims to raise awareness of these representations and prompt action for reform in line with UN Strategic Development goals.

Introduction

An interest in the consideration of how women are represented in educational materials is not new, with a focus on this topic emerging from the second feminist movement in the 1970s. In her work summarising a UNESCO report on this topic, Blumberg acknowledges that although gender bias in textbooks is a low profile global issue in a world where 72 million children have no access to schooling, it is nevertheless important because of the place of textbooks in the school environment (Blumberg, 2008). She cites a report that students spend 80 to 95% of classroom time using textbooks, with teachers basing the majority of instruction on textbooks (Sadker and Zittleman, 2007). To put it more bluntly, for school pupils textbooks *are* the curriculum (Chiappetta and Fillman, 2007, Pizzini *et al.*, 1992).

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The importance of textbooks in the curriculum has led to ongoing interest in their analysis through the lens of gender balance. Blumberg reports that textbook analysis studies has led to a near ubiquitous conclusion that textbooks show gender bias, especially in relation to mention of names in text, numbers of images showing men and women, number of citations of men and women, and a tendency to show images of men and women in stereotypical ways in countries such as Romania, China, and India (Blumberg, 2008). Some exceptions include Swedish school textbooks, which tend to show little gender bias due to government efforts to eliminate it, and textbooks in Latin American countries such as Peru, Argentina, Brazil, and Costa Rica, where government initiatives to redress gender bias are reported as "partially successful" (Stromquist, 2007).

As well as international perspectives and the work of UNESCO, there is substantial interest in the UK and Ireland in exploring issues associated with representation of women in STEM. There has been significant advocacy by the Royal Society of Chemistry regarding gender bias in chemistry (RSC, 2018), and gender bias in publishing (RSC, 2019). The findings from those analyses conclude that there are subtle but persistent effects at every stage of the academic trajectory, which when combined produce a significant effect of bias. In Ireland, government initiatives such as Ireland's Higher Education Authority Senior Academic Leadership Initiative aims to appoint 45 female professors to senior positions (Higher Education Authority, 2020). Universities in UK and Ireland sign up the Athena Swan charter which emphasises addressing gender equity in higher education (AdvanceHE, 2020). Our work is situated in this context; with substantial investment and interest in advocacy and equality in STEM, what kinds of representations are found in school textbooks in these countries?

Analysis of STEM related textbooks for gender bias has been a consideration since at least the 1970s, with a major study of chemistry textbooks completed in 1973 (Heikkinen, 1973) and reported in 1978 (Heikkinen, 1978). This work reported the analysis of ten US high school textbooks published between 1970 and 1973, involving the assessment of illustrations to identify the number of adolescents and adults, the frequency men and women appearing, and the actions being completed by those represented in images. He concluded that these books were predominantly gender unbalanced, favouring representations of men. For example, of all of the images of men and women in the textbooks, images of men comprised between 62–100% of the total (Heikkinen, 1978). The lower value in this range is from a textbook by Heikkinen himself, with the next lowest being 79%. The total number of images of men and women in these textbooks ranged from 16 to 236 (the upper value being from Heikkinen's own textbook, which included 177 images of youths, 53% of whom were women). A replicate study of new editions of these textbooks (where they existed) twenty years later and found that in general, there was no change in the gender bias found in the 1970s (Bazler and Simonis, 1991).

A more recent study in chemistry was conducted by Kahveci, which analysed Turkish textbooks for, among other things, gender representation. Names appearing in textbooks, gender variants of nouns in the Turkish language, and images showing men and women were documented to examine whether there was gender bias (Kahveci, 2010). Ten middle school textbooks, published between 1997–2004, and ten high school textbooks, published between 1999–2006, were analysed. Across all of the middle school textbooks, the ratio of men to women represented in photographs, drawings, and names was 1.4, 5.2, and 5.8 respectively, although some books in the sample did contain slightly more (up to 4) photographs of women than men. For high school textbooks in the study, the ratio of men to women represented in photographs, drawings, and names was 3.6, 30, and 5.8 respectively (Kahveci, 2010). Recent analysis of college level chemistry textbooks in the US generated similar outputs: women were represented in 30% of images and 3% of names listed (Becker and Nilsson, 2021).

In physics, there are several early studies documenting a gender bias in representation of school textbooks. A study of upper level high school textbooks for physics published between 1985 and 1991 showed images of men and boys appeared more than three times as often as women or girls (Whiteley, 1996). Analysis of physics textbooks published in 1979 and 1980 showed that in the lower level of high school for English textbooks, men and boys were represented five times more than women and girls (Walford, 1981), slightly changed from an earlier analysis of books published between 1964 and 1977, where the ratio was reported as 6 : 1 (Walford, 1980).

Modern interest in this topic has also focussed on instructional images that teachers may use in classrooms. A large-scale survey was conducted of two image banks – the European Union funded Scientix website, which is a platform for science education with over 2200 science education resources and the OERcommons website, which is a website providing open education resources for use and adaption in classrooms. Visual content analysis of these image banks demonstrated that more men than women were depicted, with the proportion of images found to be in the order boys (33.7%), girls (29.9%), men (22.7%), and women (13.7%) (Kerkhoven *et al.*, 2016).

Alongside a desire for greater representation, we place this work in a broader theoretical context that relates gender, culture, and power. Peterson and Lach (1990) published work that sought to look beyond quantifying representation and review empirical evidence for the impact on readers, considering both affective and cognitive domains. Their work surfaces the nuances needed when considering impact: readers' prior experiences lead them to take different meanings, and they will question to different extents the level and extent of representation. Crucially for this work, they point to studies that relate to *amount* of exposure to materials containing stereotypes and gender-stereotypes: simply put, the more readers are exposed to such materials, the longer attitudes normalising such stereotypes on reading are retained. To relate this work that is grounded in childrens' early education to evidence at the other end of the educational journey regarding lower engagement by women in postgraduate studies – the "leaky pipeline" (RSC, 2018) – we draw on recent work by Avargil *et al.* (2020) who describe social cognitive career theory. This is grounded in Bandura's theory on social cognition and self-efficacy. Self-efficacy considers the extent to which people believe their capability in actions they need to take will lead to desired performance (Bandura, 1986). Avargil's work applies this theory to career choice in STEM, noting that even in upper years of high school, decisions about subjects to study further are volatile (Sadler *et al.*, 2012). Avargil's work reports that career choice and the selection of chemistry depend strongly on self-efficacy concepts, and we use this as a basis to posit that as learning environments influence self-efficacy, the representation in those learning environments is an important factor to consider when looking at the broader issue of career choice in chemistry. As discussed, the extent and length of exposure to stereotypical representations likely has impact on students' ability to displace them, and as such we relate this representation to considerations regarding ultimate career journey. Additional work on differences in perception of learning environments by boys and girls in school classrooms leading to different perceptions of competency augments our choice of this stance (Cerinsek *et al.*, 2013).

Rationale and basis for current study

The literature cited aims to provide context to the current study in two ways. First, there is a clear and long acknowledged gender bias in textbooks observed from numerous studies and in studies that examine similar textbooks over a series of editions. The methodology in these studies highlight the need for quantification, so that the intensity of gender bias is recorded (Blumberg, 2008), and that this intensity is tracked over time. Second, while there are numerous studies such as those cited above, the data is at best patchy. It is difficult to gather data for comparison by country as different topics may have been analysed at different times, with different editions of textbooks. While the evidence from temporal studies is that not much changes, nevertheless a comparison of textbooks from different education systems is not possible, certainly in chemistry, and indeed there is little contemporary information available for English language chemistry textbooks. Therefore this work aims to add to the existing literature by:

1. Quantifying of the intensity of gender bias in recently published textbooks for three different but related education systems: (i) England, Wales, and Northern Ireland; (ii) Scotland, and (iii) the Republic of Ireland;

2. Characterising the representation of men and women in textbooks associated with these education systems.

The nature and goals of this work leads us to situate it within a framework of liberal feminism and in this regard we are guided by Capobianco, who describes a progressive perspective of feminism as one of generating a discourse, in our case around the topic of representation of women in textbooks (Capobianco, 2007). This acknowledged goal of generating discourse underpins our intention to document and share the number of instances observed in physical textbooks universally available – with the goal of making comparisons that we can add to the body of literature described above.

Methodology and methods

Samples

Our sample of textbooks are four senior cycle textbooks for the education system in England, Wales and Northern Ireland, Scotland, and Republic of Ireland. We surveyed experienced schoolteachers informally in each of the geographic regions so that the most popular textbooks were selected for analysis. This led to one textbook for Ireland, where the final school examination is called the Leaving Certificate, and one for England, Northern Ireland, and Wales, where we opted to choose a textbook associated with one of the three examination boards (The Oxford, Cambridge, and Royal Society of Arts (OCR)) responsible for assessment of high school subjects at a national level for the school leaving qualification, which is called the A Level. The remaining two examination boards for England were not considered, as there is considerable common content across the examination boards. For Scotland, the national curriculum is called the Curriculum for Excellence (CfE), and students in their final years sit examinations called Highers in their penultimate year and Advanced Highers in their final year, although Highers may be used to bid for university places. There is no Advanced Highers textbook for chemistry, so we sought Highers textbooks. It was difficult to discern which was more popular, so we opted to study both the main textbooks typically available. The four textbooks in this study are given in Table 1. In our study, we analysed the entire book in each case, but not any supplementary materials or online resources associated with the book. In this report, we refer to these textbooks by the referral code shown in the table. In the case of the LC curriculum, names of specific scientists are identified that students are required to know, and we have identified these in our results.

Analysis of names

We closely followed the protocols outlined by Kahveci in our analysis of text for names used (Kahveci, 2010). Unlike her study, there was almost no use of pronouns in the books sampled, so we focussed only on mention of names, noting the name and whether it was a man or a woman. In line with Kahveci's approach, multiple instances of the same name – for example in a figure legend as well as the text, or repeatedly in the text – were totalled to a count of one. In cases where the surname only was provided, this name was not included in the count, with the exception of ancient names (*e.g.* Democritus). The number and names noted were summarised and are presented. To ensure we correctly assigned names to the assigned gender, the detail of the person was checked in the Complete Dictionary of Scientific Biography. This work was done assuming binary gender norms and we acknowledge that this is not consistent with modern concepts of gender identity.

Analysis of images

In line with Kahveci's protocol, images were distinguished by whether they were an illustration or a photograph. Each image in the text and was assigned as being a photo of famous scientist, an illustration of a famous scientist, a photo of an unknown person, or an illustration of an unknown person.

Table 1 Details of textbooks used in this study

Textbook name	Date published/number of pages	Referral code	ISBN	Country: examination
Chemistry Live!	2014 (2nd Ed)/409 pages	LC	978-1-78-090467-2	Ireland: Leaving Certificate
A Level Chemistry A for OCR Student Book	2015/616 pages	OCR	978-0-19-835197-9	England: OCR A Level
Higher Chemistry for CfE with Answers	2012, revised 2015 248 pages	CfE1	978-1-44-416752-8	Scotland: Highers
Student Book for SQA Exams – Higher Chemistry Student Book	2014 (2nd Ed)/320 pages	CfE2	978-0-00-754929-0	Scotland: Highers

In all cases, the photo was categorised as being of a man or a woman or showing both a man and a woman. Rarely, a photo showed a group of people – *e.g.* four surgeons or a group at an industrial site, and if they were all of one gender, that image was assigned a count of one for that gender, whereas if it was a mixture, the image was a count of one in the category ''both''. Photos where the gender was undeterminable because the face was visible (*e.g.* a person wearing a mask) were not counted, nor were photos that did not include a face (*e.g.* hands only). Where the image was of an unknown person, a short description of their activity was noted, and subsequently coded using the approach described by Kerkhoven (Kerkhoven *et al.*, 2016). Descriptions of images for LC, OCR, CfE1, and CfE2 are given in Appendices 1–4 respectively. Textbooks were surveyed following the protocol described above to document the names observed, and whether they were men or women, and the images, recording the type of image (illustration or photograph) and a short description. Each textbook was then analysed independently by a second researcher for names and number of images and the tallies compared. Images were compiled electronically and coded by one of the researchers involved in the textbook analysis and one other researcher not involved in the text analysis. Again, tallies compared showed >95% agreement, and where there was uncertainty, the gender was assigned ''indeterminable''.

We additionally coded some images of non-scientists using the protocol described in UNESCO guidelines (Loan *et al.*, 2010). Briefly, this aimed to categorise people in images according to one of several attributes: school activity; occupational activity (formal or non-formal); domestic activity; buying activity; care or caring activity; leisure, recreational or sport activities; social activity; routine personal activity (washing, eating); a negative activity (making a mistake, breaking something, doing something inappropriate, causing problems), or a successful activity.

Results

Names of scientists

The names of scientists and other famous people mentioned in each of the textbooks is given in Table 2. As described in the methods, multiple iterations of the same name are given a count of one, and cases where the surname was not given were not included. The largest number of names was found in textbook CfE2, which names 48 famous men and 2 famous women, followed by LC, names of men (all scientists) – including 25 names required by curriculum specifications – and 1 name of a woman scientist (Marie Curie). Textbook CfE1 names 8 famous people, and all are men. Only one scientist is named in the entire OCR text – Dimitri Mendeleev (Fig. 1).

Analysis of images

Each textbooks was analysed to document the number of images (illustrations or photographs) that appeared. In order to discern images of famous people (*e.g.* a photograph of a famous scientist) from images of those representing some scientific concept or action (*e.g.* a scientist conducting an experiment or a member of the police force wearing a Kevlar jacket), these categorisations were distinguished by whether the person in the photo was ''known'' or not – that is to say whether they were a well-known scientist or personality, or whether

Table 2 Names of famous people listed in textbooks LC, OCR, CfE1, and CfE2

Names of Men	Names of Women
LC (In this curriculum, the syllabus specifies names to be known, and these are included in bold)	
Names of Men:	**Names of Women:**
Svante Arrhenius, Francis Aston, **Amadeo Avogadro**, Johann Jakob Balmer, **Henri Becquerel**, **Niels Bohr**, **Robert Boyle**, **Johannes Brønsted**, Robert Brown, Henry Cavendish, Anders Celcius, **James Chadwick**, **Jacques Charles**, **William Crookes**, **Pierre Curie**, **John Dalton**, **Humphry Davy**, Louis de Broglie, **Democritus**, **Johann Wolfgang Döbereiner**, Michael Faraday, Luigi Galvani, Joseph Gay-Lussac, Fritz Haber, **Werner Heisenberg**, Germain Hess, Felix Hofmann, Friedrich Hund, Antoine Lavoisier, **Henri Le Chatelier**, Fritz London, **Thomas Lowry**, **Dimitri Mendeleev**, **Robert Millikan**, **Henry Moseley**, **John Newlands**, Wolfgang Pauli, Linus Pauling, **Ernest Rutherford**, Erwin Schrödinger, Soren Sørensen, **George Stoney**, **J. J. Thomson**, William Thomson (Lord Kelvin), Mikhail Tswet, **Johannes van der Waals**, Alessandro Volta, Lajos Winkler	Marie Curie
OCR	
Names of Men:	**Names of Women:**
Dmitri Mendeleev	None
CfE1	
Names of Men:	**Names of Women:**
Svante Arrhenius, Heston Blumenthal, Hennig Brand, Richard Buckminster Fuller, Dmitri Mendeleev, John Newlands, Linus Pauling, James Young	None
CfE2	
Names of Men:	**Names of Women:**
Kofi Annan, Richard Axel, Heston Blumenthal, Robert Boyle, Lawrence Bragg, William Bragg, Julius Caesar, Yves Chauvin, Robert Corey, Paul Crutzen, Robert Curl, John Dalton, Johann Wolfgang Döbereiner, François Englert, Georgy N. Flyorov, René-Maurice Gattefossé, Andre Geim, Robert Grubbs, Peter Higgs, David Hockney, Martin Karplus, Harry Kroto, Nicholas Kurti, Ernest Lawrence, Michael Levitt, Nicolas LeBlanc, Henri Le Chatelier, Dmitri Mendeleev, Mario Molina, Henry Moseley, John Newlands, Barack Obama, Linus Pauling, Jackson Pollock, Sherwood Rowland, Frederick Sanger, Richard Schrock, William Sheppard, Richard Smalley, Hervé This, Mikhail Tswet, Tutankhamun, Max von Laue, Jean Valnet, Xi Jinping, John Warner, Arieh Warshel	Linda Buck, Dorothy Hodgkin, Latezia Stanghellini

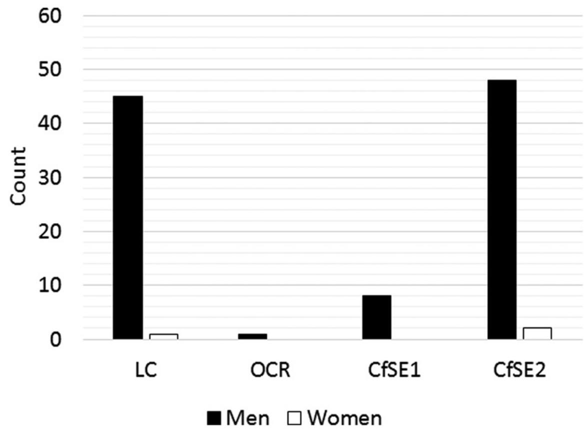

Fig. 1 Number of times names of men and women are mentioned in the textbooks analysed (where multiple counts of the same name is 1 count).

they were stock images used to represent a particular scenario or concept. The results are summarised in Table 3.

This analysis showed that Irish school textbook LC had the largest number of images of people, with 68 photos of known and unknown people. 35 of these were of men who were known scientists – typically images or etchings of famous scientists from the history of chemistry. No individual images of a woman who was a known scientist appeared in this book, while there was one image of Marie Curie together with her husband Pierre. Of the remaining images, showing unknown or stock images, 24 were of men and 4 were of women. These images are further analysed below. 2 of the remaining images were assigned as being a man by the first coder but queried by the second, and so to remove any bias, they were coded as indeterminable.

Book OCR had 15 images of people, with one known person (Mendeleev) and 14 unknown, 5 of whom were men, 4 of whom were women, and the remainder indeterminable. These are further analysed below.

For the Scottish textbooks, CfE1 also had a total of 11 images. 2 were of famous men (Mendeleev and Pauling) and 9 were unknown stock images. CfE2 had a total of 37 photos; 14 photographs of known men comprising of mostly famous scientists from history and modern times (such as Peter Higgs) as well as famous personalities (such as Barack Obama and Heston Blumenthal), one photo of a famous woman (Dorothy Hodgkin), and one photo showing a group of Nobel prize winners naming both Richard Axel and Linda Buck. Of the remaining 23 photos of unknown people, 14 were of men, 6 of women, and 3 with both men and women. These images are analysed further below.

Analysis of "unknowns" – representations in textbooks

In order to explore representations further, images (photographs and illustrations) of non-famous scientists were analysed separately.

We first explored the images showing science in action, such as illustrations or photographs of people conducting a scientific task (such as performing a titration or using a chromatograph) or working in a situation requiring a scientific basis (such as performing medical procedures of conducting forensic investigation). The number of scientists and non-scientists in each textbook are summarised in Table 4. The Irish and Scottish textbooks each showed more scientists who were men than those who were women (17 : 2, 4 : 1, 4 : 1 for LC, CfE1, CfE2 respectively), while the English textbook OCR showed 3 photos of scientists who were men and 4 scientists who were women.

The second set of images of unknown people were non-scientists, and these tended to be images showing the application of chemistry in everyday life, or illustration of the ubiquity of chemistry (and chemicals) in daily interactions. The UNESCO report detailing approaches to exploring gender bias in textbooks identifies several possible attributes of pictures commonly found in textbooks, and we used these attributes as the basis to characterise the images found (Loan *et al.*, 2010). Of those attributes named, we identified images that aligned with occupational activities (formal or informal), leisure or recreation, domestic activity, buying activity, routine personal activities

Table 3 Numbers of images in textbooks analysed that were of known men or women, unknown men or women, included both known men and women (marked *a*), both unknown men and women (marked *b*) or where gender was indeterminable (marked *c*)

	Known Man	Unknown Man	Known Woman	Unknown Woman	Other
LC: 409 pages; 68 categorised images					
Illustrations:	25	2	0	1	0
Photographs:	10	22	0	3	$1^a + 1^b + 3^c$
OCR 616 pages; 15 categorised images					
Illustrations:	1	1	0	0	0
Photographs:	0	4	0	4	5^c
CfE1 248 pages; 11 categorised images					
Illustrations:	0	4	0	0	0
Photographs:	2	1	0	2	$1^b + 1^c$
CfE2: 320 pages; 37 categorised images					
Illustrations:	0	1	0	0	0
Photographs:	14	12	1	5	$1^a + 3^b$

Table 4 Categorisation of images of unknown people as being scientists or non-scientists

Textbook (number of categorised images)	Gender representation (M = man, F = woman, B = both, N = indeterminable)
LC (32)	
Scientist: 21	17M 2F 1 B 1N
Non-scientist: 11	8M 2F 1N
OCR (14)	
Scientist: 9	3M 4F 2N
Non-scientist: 5	2M 3N
CfE1 (9)	
Scientist: 5	4M 1F
Non-scientist: 4	1M 1F 1B 1U
CfE2 (22)	
Scientist: 8	4M 1F
Non-scientist: 14	1M 1F 1B 1U

Table 5 Attributes of images of unknown, non-scientists in each of the textbooks based on UNESCO categorisations described by Loan *et al.* (2010)

Attribute	LC	OCR	CfE1	CfE2
School activity	—	—	—	—
Occupational activity, formal or non-formal	5 M	1 M*	—	5 M
Domestic activity	1 F	—	—	2 F
Buying activity	1 F	—	1 M	1 F
Care or caring activity	—	—	—	—
Leisure, recreational or sport activities	2 M	1 M	—	1 M
Social activity	—	—	—	—
Routine personal activity (washing, eating)	1 F	—	—	—
Negative activity	—	1 M*	—	1 F
Successful activity	—	—	—	—

(washing, eating, *etc.*), and a negative activity. The counts are summarised in Table 5 and described below.

Overall, photographs of men tended to align with those activities characterised as occupational and leisure and recreation, whereas photographs of women tended to align with domestic and buying activities. 5 of the 11 photographs in the Irish textbook LC showed men in occupational activities, including three images of policemen, one of a farmer, and one man with a tracker dog. Similarly, 5 of the 14 photos in the Scottish textbook CfE2 showed men in occupational situations – spraying a car, at a car show, a soldier, a wine sampler, and in an illustration for a dry-cleaning advertisement. 1 of the photos in CfE2 showed a photograph of a woman working in a dry cleaners, and this was the only photo in any of the four textbooks showed a non-scientist woman in an occupational setting.

3 photos – 2 in LC and 1 in CfE2 – showed men in sport and recreation scenarios (an athlete, a cricketer, a man sun-bathing/reading) while none of the textbooks showed women in sport and recreation scenarios. There were 3 images of women in domestic scenarios and buying scenarios (woman pushing a trolley in supermarket in both the Scottish textbooks, and additionally a woman at a fridge in CfE2). No men were in photographs with this attribute.

Two images of woman conducting routine personal activities were in the Irish textbook LC, with an illustration of a woman showing the effects of hair conditioner, along with an image of a woman having hair bleached. There were no images of men in the personal activity category. Finally, one image each of a man and a woman were assigned with a negative attribute; a man being breathalysed in OCR, and a woman holding a cigarette packet in CfE2.

Discussion

This research contributes to a long-standing body of literature exploring gender bias in school textbooks. Our data illustrate that whatever measure is taken, there is a gender bias in the representation of men and women in the textbooks we analysed. In the analysis of four commonly used textbooks in the Republic of Ireland and the United Kingdom, we noted in all cases more names of men than names of women who were famous scientists and others, and more images of men than women. When we removed from the analysis famous scientists, which because of syllabus history skews the representation towards men more than women, we found that all textbooks had more images of "unknown" men than they did of "unknown" women, and in the case of two of the textbooks, these differences were severe (25 unknown men compared to 4 unknown women in textbook LC; 14 unknown men compared to 6 unknown women in textbook CfE2). Further analysis of these representations of unknown men and women showed that in all but one case (textbook OCR), the representation of scientists was predominantly of men. Of the remaining images that were of non-scientists, men tended to be represented in images depicting occupational or leisure activities, while women tended to be in images associated with domestic or buying activities. The latter attribute of the "domestic realm" has been observed in textbooks in Kenya and Thailand (Singh, 2015). In the case of the English textbook, it would at first appear that there is no bias in terms of the scientists reported with regards to the criteria we have listed, although it should be pointed out that several names of men are mentioned that are implicit to chemistry topics (*e.g.* Avogadro constant, Pauling electronegativity, Hess's law, Boltzmann's distributions, le Chatelier's principles, Cahn–Ingold–Prelog priority rules, Markownikoff's rule, Arrhenius equation, Born–Haber cycles, (×2), Kekule model, Tollens' reagent). Given the frequency of naming multiple laws, constants, equations and rules after scientists who are men, there will be numerous references to their work throughout both the curricula and textbook, but the 'historical factor' means the work of scientists who are women is obscured. These names will become cultural touchstones for students as they progress in their (scientific) careers, so the poor visibility of women in this context should not be ignored.

Our work grew out of a concern regarding representation and its subsequent impact on interest in pursuing study in the chemical sciences, grounded in work in childhood reading (Peterson and Lach, 1990), social cognitive career theory (Avargil *et al.*, 2020), and data such as that from the Royal Society of Chemistry's study on representation in chemistry (RSC, 2018). The low extent of representation of women in the textbooks surveyed in the context of this work leads us to conclude that there is consistent and repeated representation of scientists as men to the detriment of opportunities to represent scientists as women, especially in cases where stock imagery is used to represent scientists "doing science". While Peterson and Lach prompt caution in making broad declarations of impact – each reader will bring their own prior experience regarding assumptions about representation – we believe this extent of representation will impact those whose backgrounds have already reinforced gender stereotypes most. As such, the concerns include but extend beyond gender and extend into issues relating to class (Ullah and Skelton, 2013).

The United Nations Sustainable Development Goals (SDG) Target 4.7 aims to "*by 2030 ensure all learners acquire knowledge and skills needed to promote sustainable development, including among others through education for [...] gender equality*" (UN, 2015). Of all the education targets set by the UN under

Goal 4, Target 4.7 is the one that focuses on the human and cultural aspects of education. However, many textbooks across all areas of the primary and secondary curricula around the world perpetuate a consistent diminishment of the contributions and work of women, whether by their omission or through their depiction mainly in submissive roles (Cipolla-Ficarra *et al.*, 2018). Abdelhay and Benhaddouche directly challenged this in textbook illustrations, hypothesising that gender bias has "negative impacts on the learners' construction of identities and perceptions" (Abdelhay and Benhaddouche, 2015). The role of stereotypes in shaping cultural expectations and societal norms has also been flagged in the GEM policy report #28, framing this issue as a contributing factor to be resolved in order to reach Target 4.7 (UNESCO, 2016).

Textbooks are just one element of education but the issues they present are compounded by limited inclusion education programmes for teachers and a gap between the declarations and the actions of countries in preparing teachers to teach more inclusively. Many countries created laws or policies in the name of inclusive education in order to fulfil SDG4, but the 2019 GEM policy paper #43 highlights how problematic this is in terms of delivering the training required, and in turn the associated curriculum changes necessary (UNESCO, 2020b). A recent report by GEM on Inclusion and Education highlighted how women continue to be under-represented in textbooks globally which directly conflicts with the goal of universal design.

The analysis of images in this work raises an important point about image banks and the need for increased diversity in their offerings. At the moment they embed stereotypes based on their current catalogue, which is particularly problematic for textbooks as publishers frequently mine these databases to illustrate the life of a scientist and the physical shape of the instrumentation and apparatus used in the chemical sciences. However, there is a documented exaggeration of stereotype and systematic underrepresentation of women in searches of image databanks, which creates a pressing need to improve representation therein (Kay *et al.*, 2015). These biases are immediately evident in the results above, limiting the visibility of women scientists and shaping the perspective of students who read them on a daily basis.

Implications

It is likely that practicing school teachers are fully aware of the issues highlighted in our work, and may already draw on external resources or their own agency to influence the representations pupils are exposed to. Indeed an analysis of textbook usage in England demonstrated that 64% of teachers used textbooks in a supplemental manner, as part of a suite of resources to deliver the curriculum (Oates, 2014). Our work aims to highlight in clear terms the representations that do and do not exist in the text-based materials, so that teachers may opt to supplement resources selected with materials that offer a wider representation. Recent examples include the *Compound Interest* site hosting infographics highlighting women in chemistry (Compound Interest, 2021), the compilation of resources in the RSC periodical *Education in Chemistry* (2021), profiles of professional chemists in the American Chemistry Society's periodical *Chemical & Engineering News* (2021) and a range of resources – many curriculum-linked – on the *Finding Ada* website (2021).

However, placing emphasis on teachers to redress the balance is unsustainable and untenable in the long term, and we urge advocacy with textbook publishers and curriculum developers to ensure a much more vibrant and diverse representation of who does chemistry in their materials provided. While the "chemical history" factor will always be prevalent, demonstrating the inputs of women both in regards to the history of chemistry, and perhaps more importantly in the *practice* of current chemistry is vital. Stock images used in textbooks should draw from a diverse pool of images available, and while our work here focusses on gender, there are similar issues regarding race and ethnicity that deserve attention. We call on professional bodies and publishers to ensure that modern textbooks reflect the diverse range of pupils using them in their representation of science.

Conclusions

In a society where students are constantly exposed to a barrage of unconscious messages through advertising, we should be considering how we represent the chemical sciences. This work intends to highlight gender representation in the important domain of school textbooks, to raise awareness of this representation, and to call on publishers and textbook authors to do better in representing gender. Minimising representation should be a serious priority for educational professionals in considering teacher education, curricula and publishing guidelines. Students deserve to receive an education where everyone is visible and stereotypes have been removed (UNESCO, 2020a).

Conflicts of interest

There are no conflicts to declare.

Appendix 1: analysis of images in textbook "LC" (*Chemistry Live!*, ISBN: 978-1-78-090467-2)*

Images where person is not known

Figure	Description	Assigned	Image type
2.26	Man with a tracker dog	M	P
3.15	Scientist (man) using a laser	M	P

Table (*continued*)

Figure	Description	Assigned	Image type
3.16	Scientist (man) with AAS	M	P
3.6	Student, gender undeterminable, using a spectroscope	U	P
4.15	Student (man) using mass spec	M	P
5.1	Man using medical laser	M	P
5.38	Man and woman vet treating a dog	B	P
5.46	Policeman wearing Kevlar	M	P
5.5	Athlete (man)	M	P
8.9	Patient being treated with radiation	U	P
11.4	Scientist (man) with CHN instrument	M	P
12.9	Illustration of girl looking in mirror before and after using hair conditioner	F	I
13.1	Scientist (man) doing a titration	M	P
13.13	Student, gender underterminable, pipetting	U	P
14.3	Girl showing hair and effects of bleaching using peroxide	F	P
16.15	Scientist (man) performing demonstration	M	P
16.5	Policeman doing road speed test	M	P
17.1	Cartoon of man on treadmill	M	I
18.11	Student (man) doing pH titration	M	P
18.5	Scientist (man) using pH meter	M	P
19.10	Student (man) doing a titration	M	P
19.24	Student (man) testing using a colorimeter	M	P
19.26	Scientist (man) using colorimeter to test for nitrates	M	P
21.1	Scientist (man) synthesising a drug	M	P
21.30	Scientist (man) working in an oil refinery	M	P
21.43	Man filling a car with petrol	M	P
23.34	Policeman doing breathalyser test	M	P
23.59	Scientist (man) using GC	M	P
23.62	Scientist (man) using HPLC	M	P
23.64	Student (woman) using an IR	F	P
23.65	Student (woman) using UV/vis	F	P
None	Cartoon of farmer (man) with bags of fertiliser	M	I

Images where person is known

Figure	Description	Assigned	Image type
2.2	Image of Democritus	M	I
2.3	Image of John Dalton	M	I
2.4	Image of William Crookes	M	I
2.9	Image of J.J. Thomson	M	P
2.12	Image of Robert Millikan	M	P
2.15	Image of Ernest Rutherford	M	I
2.18	Image of Ernest Rutherford (different to above)	M	I
2.21	Image of James Chadwick.	M	I
3.1	Image of Neils Bohr	M	I
3.19	Image of Werner Heisenberg	M	P
3.22	Image of Schrodinger	M	I
4.1	Image of Robert Boyle	M	I
4.2	Image of Humphrey Davy	M	I
4.4	Image of Dobereiner	M	I
4.6	Image of John Newlands	M	P
4.7	Image of Dmitri Mendeleev	M	I
4.9	Image of Moseley	M	P
4.11	Image of Francis Aston	M	P
5.29	Image of Linus Pauling	M	I
8.1	Image of Henri Becquerel	M	I
8.2	Image of Pierre and Marie Curie	B	P
9.2	Image of Amedeo Avogadro	M	I
10.3	Image of Anders Celcius	M	I
10.4	Image of William Thomson (Lord Kelvin)	M	I
10.6	Image of Robert Boyle (different to above)	M	I
10.12	Image of Jacques Charles	M	I
10.18	Image of Joseph Gay-Lussac	M	I
10.21	Image of Amedeo Avogadro (different to above)	M	I
12.2	Image of Svente Arrhenius	M	I

Table (*continued*)

Figure	Description	Assigned	Image type
12.5	Image of Johannes Brønsted and Thomas Lowry	M	P
17.3	Image of Henri Le Chatelier	M	P
18.2	Image of Søren Sørenson	M	P
20.1	Image of Michael Faraday	M	I
21.2	Image of Humphry Davy	M	I
21.48	Image of Germain Hess	M	I

**Assigned*: Woman (F), Male (M), Both (B), Unknown (U). *Image type*: Photograph (P), Illustration (I)

Appendix 2: analysis of images in textbook "CfE1" (*A Level Chemistry A for OCR Student Book*, ISBN: 978-0-19-835197-9)*

Images where person is not known

Figure	Description	Assigned	Image type
2.3	A scientist using a mass spectrometer	F	P
3.2	A meteorologist releasing a helium balloon	M	P
4.2	A scientist inverting a volumetric flask	U	P
17.1	A scientist looking at a mass spectrum	F	P
17.5	Paralympic sprinters racing	M	P
17.8	A police officer breathalysing a male driver	M	P
19.1	A mountaineer at high altitude	U	P
21.1	A student using a digital pH meter	F	P
22.7	Applying a cold pack to elbow	U	P
25.3	A group of surgeons performing an examination in the nineteenth century	M	I
25.6	A group of workers at a TNT munitions factory	U	P
28.7	A scientist working on organic synthesis	F	P
29.1	A researcher using an NMR spectrometer	M	P
29.2	A nurse with a patient at an MRI scanner	U	P

Images where person is known

Figure	Description	Assigned	Image type
7.1	Dimitri Mendeleev	M	I

**Assigned*: Woman (F), Male (M), Both (B), Unknown (U). *Image type*: Photograph (P), Illustration (I)

Appendix 3: analysis of images in textbook "CfE1" (*Higher Chemistry for CfE with Answers*, ISBN: 978-1-44-416752-8)*

Images where person is not known

Figure	Description	Assigned	Image type
2.3	Illustration of alchemists – all male	M	I
2.24	Painting showing discovery of phosphorous – all male	M	I
2.36	Image of 4 soldiers in first world war	U	P
7.1	Cartoon of man showing body parts consisting of proteins	M	I
11.1	Photo of woman pushing shopping trolley in supermarket	F	P
15.2	Photo of scientist (man) checking experiment temperature	M	P
17.8	Photo of forensic arsenic investigators	B	P
RC.1	Photo of woman at fumehood	F	P
RC.11	Illustration of man performing a titration	M	I

Images where person is known

Figure	Description	Assigned	Image type
2.4	Image of Mendeleev	M	P
3.8	Image of Linus Pauling	M	P

**Assigned*: Woman (F), Male (M), Both (B), Unknown (U). *Image type*: Photograph (P), Illustration (I)

Appendix 4: analysis of images in textbook "CfE2" (*Student Book for SQA Exams – Higher Chemistry Student Book*/ISBN: 978-1-44-416752-8)*

Images where person is not known

Figure	Description	Assigned	Image type
1.2.25	Picture of nurse (woman) with patient likely man at MRI	B	P
1.3.33	Photo of two women and one man at a computer	B	P
1.3.41	Photo of woman working in a dry cleaners	F	P
1.3.42	Cartoon advertisement showing outline of man holding a dry cleaning sign	M	I
2.1.7	Picture of hand showing nail varnishing	U	P
2.1.8	Photo of person likely man spraying car	M	P
2.1.11	Photo of man smelling a glass of wine	M	P
2.4.8	Photo of woman holding her nose at the smell from a fridge	F	P
2.5.2	Photo of a student (man) stirring a solution	M	P
2.5.12	Photo of scientist (man) holding chocolate bar	M	P
2.7.1	Two photos in one image – one of a man and one of a woman applying skin cream	B	P
2.7.5	Photo of a cricketer (man) wearing sun cream	M	P
2.7.9	Photo of mosaic of Roman emperor Justinian	M	P
2.7.17	Photo of woman holding cigarette pack	F	P
3.1.1	Photo of woman in supermarket with trolley	F	P
3.1.3	Photo of group of doctors (men) treating children	M	P
3.1.23	Photo of soldier (man) being treated for mustard gas poisoning	M	P
3.3.14	Photo of two men beside a car at a car show	M	P
3.4.4	Photo of man sunbathing while floating on Dead Sea	M	P
3.5.1	Photo of scientist (man) performing HPLC	M	P
Fig. 7 p314	Photo of scientist (woman) at mass balance	F	P
Fig. 9 p315	Photo of student (man) using pipette	M	P

Images where person is known

Figure	Description	Assigned	Image type
1.2.5	Stamp with Georgy N Flyorov	M	P
1.2.8	Etching of John Dalton	M	P
1.2.10	Etching of Johann Wolfgang Dobereiner	M	P
1.2.11	Photo of statue of Mendeleev	M	P
1.2.12	Photo of Henry Moseley	M	P
1.2.26	Photo of Peter Higgs	M	P
1.2.31	Photo of Harry Kroto	M	P
1.2.38	Photo of Andre Geim	M	P
1.2.52	Photo of Linus Pauling	M	P
1.3.7	Photo of Dorothy Hodgkin	F	P
2.2.11	Photo of Frederick Sanger	M	P
2.3.4	Photo of Nobel prize group with Richard Axel and Linda Buck named	B	P
2.3.13	Photo of Heston Blumenthal (not named)	M	P
2.7.11	Photo of F Sherwood Rowland	M	P
2.7.15	Photo of Barack Obama	M	P
3.2.6	Photo of Max Ernst Bodenstein	M	P

**Assigned*: Woman (F), Male (M), Both (B), Unknown (U). *Image type*: Photograph (P), Illustration (I).

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