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College Chemistry Textbooks Fail on Gender Representation

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ABSTRACT: This study examines gender representation in 10 current (2016−2020) US college-level general chemistry textbooks. On average, females were found to constitute 30% of images and 3% of the named science, technology, engineering, math, and medical (STEMM) professionals in the index. A male name appears on average every four pages of text, while a female name appears every 250 pages of text. Male overrepresentation is not driven by a pedagogical need to include specific individuals, since the textbooks only have eight names in common. Gender imbalance was ubiquitous among all publishers examined and observed in both traditional and electronic texts. We speculate that male overrepresentation in chemistry textbooks reflects and perpetuates unconscious gender bias in STEMM.

KEYWORDS: *First-Year Undergraduate/General, High School/Introductory Chemistry, Curriculum, Textbooks/Reference Books, Minorities in Chemistry, Student-Centered Learning, Women in Chemistry*

■ INTRODUCTION

Textbooks define the individuals, values, events, concepts, and skills that are considered legitimate in a discipline. They reflect the mindset of the experts who author the texts and also illuminate the messaging a student receives about the subject. Thus, textbooks provide a glimpse into the biases, either conscious or unconscious, among the professionals in the discipline and the indoctrination received by future practitioners.[1−3]

Exploring possible sources of bias in science, technology, engineering, math, and medicine (STEMM), such as textbooks, may reveal cultural norms that can go unnoticed at the conscious level. These unconscious elements influence aspiring students by shaping their ideas about who can become a scientist, which, in turn, can affect their sense of belonging, motivation, and persistence in STEMM.[4,5]

The purpose of this study was to examine if general chemistry textbooks reflect a gender bias. General chemistry textbooks were chosen for study because this course plays a gatekeeping role to a vast array of professional careers in health, medicine, and science (e.g., chemistry, biochemistry, biology, kinesiology, environmental science). Furthermore, students typically take this course early in their educational journey, which is a critical time for learning about disciplinary norms and formulating career goals and aspirations. Thus, if general chemistry textbooks are gender biased, it may deter the persistence of women in STEMM majors and, thereby, contribute to the underrepresentation of women in these fields.

In this study, document analysis was used to examine the gender representation in college-level general chemistry textbooks. We examined 10 US general chemistry textbooks (two-semester, majors-level) published between 2016 and 2020. The gender representation was determined through image analysis and the quantification of the STEMM professionals listed in the indices and their frequency of occurrence.

■ MATERIALS AND METHODS

Textbook Selection

An online search identified 30 prospective general chemistry textbooks (two-semester, majors-level) currently available in the US. The texts were sorted on the basis of publication year, yielding 21 texts published within the last four years (2016−2020). The 21 texts were then grouped by publisher and ranked by edition number. The edition number was applied as a proxy for textbook usage since continued reissue suggests a sustained and high level of textbook sales. Multiple texts included an overlap of authors, and therefore, to avoid redundancy, only the highest edition text by a given author was retained, which reduced the pool to 16 texts. Ten of these books, representing the highest edition texts from seven publishers during 2016−2020, were chosen for the study. In addition, five supplementary texts were also examined. Four were first editions that correspond to four of the 10 textbooks under investigation; these were studied to provide a temporal comparison. The first edition texts were chosen on the basis of the ease of obtaining a copy through second-hand sources. The fifth supplemental text examined was a college-level non-majors chemistry textbook designed by the American Chemistry Society (the ACS has not produced a two-semester, majors-level text).

Image Analysis

The examination of photos and illustrations is a well-established method to assess the ratio of men and women in

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textbooks.[2,6−8] This method does not purport to explicitly determine the biological sex or gender identity of the individuals in an image. Instead, the goal is to ascertain what a reader of the text would likely perceive as the sex of the person in an image based on gender presentation cues (style of dress, physical characteristics, etc.).

In this study, the depictions of people (photos, illustrations, drawings, etc.) were examined on every page from the beginning of the text up to the first appendix. Over 30% of the people either were readily identifiable (e.g., Abraham Lincoln, George Washington), had names included in the figure caption, or the caption contained gendered descriptors (e.g., she, his, girls, policeman). The remaining images were evaluated using visual gender presentation cues. If an individual in an image could not be evaluated because the image was too small, blurry, etc., then it was not included in the analysis.

Images were analyzed and quantified to determine (1) the total number of male and female depictions in each text, (2) the number of images containing only female, only male, or both male and female figures, and (3) the number of images in which the person's name was included. This methodology is analogous to that used by others,[9,10] with the exception that, due to the small sample size, images of youths were not analyzed separately in this study. We mathematically combined the published raw data for adults and youths in the prior studies to allow for a direct comparison to our results.

Index Analysis

The name of every individual cited in the index was documented, and each person was categorized as male or female on the basis of the gendered pronouns used as descriptors. Most people cited in the index were prominent STEMM professionals credited with experimental or theoretical research connected to the topics discussed in the text. The index was also used to determine the number of unique pages of the textbook on which the name was specified; pages in the index were counted if it referred to the individual or to a constant, unit, equation, or other parameter that bears the name of the individual. If a parameter was named after an individual but the gender of the person was not identifiable within the text, this parameter was excluded. An estimate of the frequency of name occurrence in the textbook was determined by the percentage of pages with named STEMM people and parameters divided by the total number of pages between the preface up to the first appendix.

Study Limitations

This study is framed within the context of binary definitions of sex and gender. However, variations of biological sex exist at the chromosomal, hormonal, gonadal, and genital levels, and there are over 50 gender identities.[11,12] Thus, the use of the terms male and female is overly simplistic and does not capture the diversity of human sex and gender.

The interpretation of gender presentation cues from images is subject to human bias. Prior studies analyzing textbook images, however, have shown little variability among evaluators.[9,13] The images in this study included over 30% with identifiers beyond physical appearance alone, and most other images contained strong visual cues (e.g., beard, male pattern baldness, breasts, etc.). Thus, the potential impact of human bias in this study is considered nominal.

The index analysis underestimates male representation. As the books were examined, it was noted that some named individuals in the text were not included in the index, and in every case, the individual was male. Furthermore, many usages of parameters named after men were not indexed. The units Kelvin and Joule, for example, were typically only indexed when first introduced but can be found in many other portions of the text.

■ RESULTS

On average, the texts contained 50 images (photos, illustrations, drawings) with human figures. The people in the images were overwhelmingly scientists, followed by individuals at work, engaged in sports, and patients receiving care from a medical professional.

By counting every human figure depicted, the average percentage of males (70%) was determined to be significantly higher than that of females (30%). This metric, however, can be skewed by a single photo with a large number of individuals represented. Therefore, the number of images with only males, only females, or both were also counted. The average percentage of images that contained only males (65%) was significantly higher than that with only females (24%); the remainder (11%) contained both males and females. Taken together, the data reveals that males are represented more frequently among the textbook photos, illustrations, and drawings.

Images in which the name of the person was specified were also counted. This approach provides a glimpse into the status of the people in the images, since providing a name suggests a relative degree of importance. The percentage of the named individuals that were male (87%) dramatically outnumbered named individuals that were female (13%). See Supporting Information Table S1 for textbook-specific image data.

We searched the published literature and found no prior studies on gender representation in US college chemistry textbooks. However, image analysis has been conducted on US high school chemistry textbooks;[9,10] a comparison with our data is presented in Table 1. The results indicate that the percentage of female images in current US college chemistry textbooks is comparable to that of US high school chemistry textbooks from the late 1970s and early 1980s. The impact of low female representation in textbooks at the high school and college levels is likely different yet compounding. In high school, female students may be discouraged from pursuing a STEMM career, while at the college level, it may alter the career aspirations of women in STEMM majors.

A second measure of gender representation was obtained by the quantification of STEMM professionals listed in the index. In total, there were 360 unique names across the 10 textbooks, only 12 of which were women (a list of these women can be found in the Supporting Information Table S2). A comparison of the number of male and female STEMM professionals for each textbook (Figure 1 and Table S3) reveals that female STEMM professionals are underrepresented in every text.

The index was also examined to estimate the frequency with which male versus female names appear in the text (Table S3). On average, a male name appears every four pages while a female name appears every 250 pages. In other words, male names appear 60 times more frequently. If we translate this into the more tangible scale of time, females get 1 min of representation for every hour of time devoted to men.

In some classrooms, traditional textbooks are being supplemented and/or replaced by electronic books and other digital media (e.g., OER Commons, Boundless, MIT Open-

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Table 1. Image Analysis of US Chemistry Textbooks

Course Level	Number of Texts	Publication Years	Percentage of Females	Percentage of Named Females	Source
College	10	2016−2020	30	14	This study
High school	7	1978−1987	27	13	Bazler et al.[9a]
High school	5	1973−1975	23	11	Heikkinen[10a]
High school	7	1963−1966	6	2	Heikkinen[10a]
High school	5	1942−1948	9	6	Heikkinen[10a]

[a]Raw data collected on named adults, unnamed adults, and youths from these papers was used to calculate the percentages of females and named females.

Courseware, Open Textbook Library, OpenStax). These open-source and low-cost materials have significant growth potential, and therefore, we examined an OpenStax eBook, *Chemistry 2e*,[18] as one of the 10 texts in this study. We found the same degree of gender disparity in the OpenStax eBook as in the traditional paper texts (see entry FTLR-2 in Figure 1). This is consistent with a prior study in which online science education resources for primary school children were shown to be systemically gender biased[24] and also correlates with the persistent underrepresentation of female scientists on digital sites such as Wikipedia.[25]

Professional societies reflect and shape disciplinary norms, and the American Chemical Society (ACS) is the largest scientific professional society in the world. The only college-level ACS text, *Chemistry in Context*,[26] was designed specifically for non-science majors. Since this book did not meet the criteria of a two-semester majors-level text, it was examined as a supplement to the primary study. *Chemistry in Context* is close to gender parity in the images (45% women overall and 50% of named individuals), but the index analysis reveals that only 15% of the named STEMM professionals are women. Furthermore, male STEMM names appear five times more frequently, and all non-STEMM professionals listed in the index are male (e.g., George Bush, Kofi Annan, Beethoven, Edward Humes, Jules Verne).

The observed underrepresentation of women in college-level general chemistry texts prompted us to explore possible contributing factors. One proposed explanation for the pervasive gender imbalance is the historical approach often used to teach science.[7] Many textbooks trace key discoveries through time, and since men are credited (though sometimes incorrectly) with the majority of early discoveries, this approach can lead to an overrepresentation of men. To investigate this hypothesis, we examined which STEMM professionals were included in all 10 current general chemistry textbooks to identify how many individuals were considered pedagogically "essential". We found that only eight scientists, all male, were included in all 10 books (Table S4). Given that the average textbook mentions 97 STEMM professionals, there is ample room to include more women.

We then speculated that the overrepresentation of male STEMM professionals may be due to a lack of textbook updating over time. To explore this hypothesis, the first editions of four of the 10 textbooks were selected for index analysis. The first editions were published between 1972 and 1987, and the current editions were between 2017 and 2019; on average reflecting a 39 year timespan (Table S5). We found that many new names were added as the editions evolved (ranging from 39 to 119), and on average, only 30% of the names were the same between the first and current editions. Thus, we conclude that substantial revisions of the texts occurred.

The revisions from the first to current editions, however, did not improve gender parity. Overall, the vast majority of names added were male (Figure 2 and Table S5). In fact, the percentage of female STEMM professionals listed in the index from the first to current editions decreased in two texts, stayed the same in one, and increased in one (Table S5).

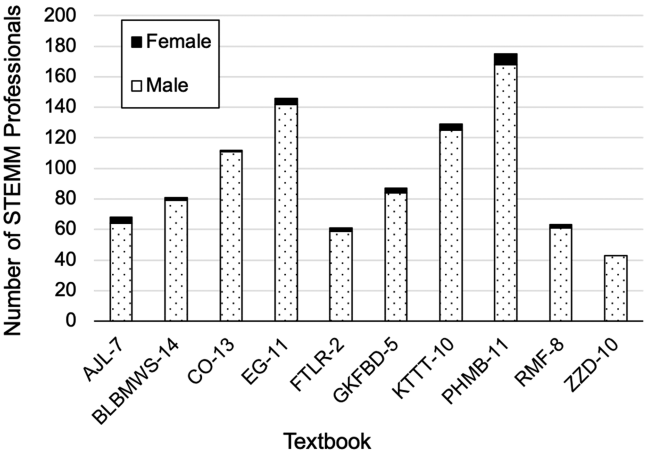

Figure 1. Index analysis of current (2016−2020) US college-level general chemistry textbooks. Textbooks are identified by the first letter of the last name of each author followed by the edition number.[14−23]

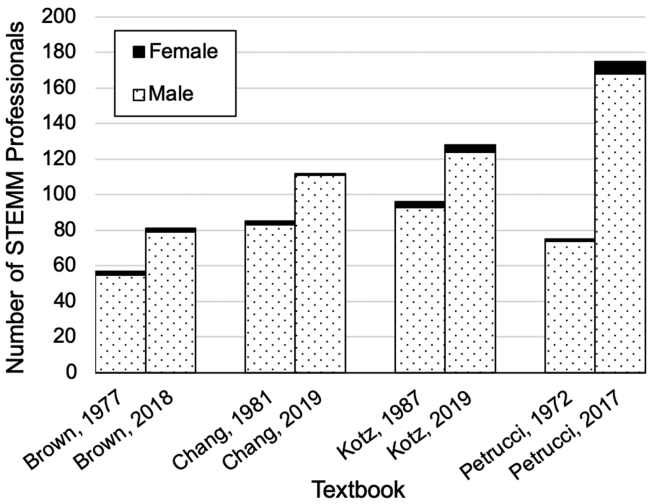

Figure 2. Temporal comparison of US college-level general chemistry textbooks. Index analysis was performed on first[27−30] and current[15,16,20,21] editions of US chemistry textbooks. The *x*-axis lists the first author of each text followed by the publication year.

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DISCUSSION

In current (2016−2020) college-level general chemistry textbooks, image analysis reveals that males are depicted more frequently (70% male, 30% female), are in more images (65% male, 24% female, 11% both), and are more often named (87% male, 13% female). Gender representation in images is important because female students demonstrate a higher comprehension when performing a science task after exposure to a female image while male students show a higher comprehension when performing a science task after exposure to a male image.[31] The image bias in US college chemistry textbooks, therefore, not only reinforces a disciplinary culture that is not inclusive but also negatively impacts the academic success of female students while advantaging the success of male students.

Index analysis of current general chemistry textbooks reveals that only 12 of the 360 unique names in the 10 texts are women and, on average, a male name appears every four pages while a female name appears every 250 pages. The percentage of female STEMM professionals in the indices ranged from 0 to 6% with an average of 3% (Table S3). This percentage is disturbingly low, especially given that 40% of the 2019 National Academies of Science inductees were women[32] and that 49% of undergraduate chemistry majors are female.[33]

The underrepresentation of female STEMM professionals is ubiquitous among all publishers examined and occurs in both electronic and traditional texts. Furthermore, the paucity of women is not a result of a lack of textbook updating nor driven by a pedagogical need to include certain individuals. The common denominator appears to be a gender bias, either conscious or unconscious, among the individuals who make decisions about what content to include. A recent study has shown that male faculty in STEMM are the most resistant to acknowledging STEMM gender bias.[34] The authors of the 10 current texts were predominantly male (83%) as were the authors of the four first edition texts (100%). The predominance of male authors combined with the reluctance of male STEMM faculty to acknowledge gender bias may contribute to the persistent underrepresentation of females in chemistry textbooks.

In a temporal comparison, we found the representation of females in current college-level general chemistry textbooks to be comparable to textbooks published in the 1970s and 1980s (Table 1 and Figure 2). The lack of improvement is particularly striking given that equal rights for women were articulated in Title IX of the 1972 Education Amendments, which states "No person in the United States shall, on the basis of sex, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any education program or activity receiving Federal financial assistance".[35] After Title IX, many publishers produced textbook guidelines to mitigate the gender gap.[36−38] Britton and Lumpkin, however, observed little progress between pre- and postguideline children's textbooks and concluded "Publishers seem more inclined to publish the guidelines than take measurable, objective actions to enforce them".[36] Our data, collected 43 years after Britton and Lumpkin's publication, supports their conclusions. Clearly, sustained attention along with inducements and/or repercussions will be needed to eliminate gender bias in STEMM textbooks.

New editions of general chemistry textbooks are issued approximately every 2−3 years. Updating images to improve gender balance could be done easily, while altering the ratio of STEMM professionals will require some rewriting of the text. One strategy could be for the authors to extend general chemistry core concepts to modern applications, which would easily allow for the integration of current women in STEMM. Biographical information for many female chemists can be obtained from books including *African American Women Chemists*, *European Women in Chemistry*, and *Women in Chemistry: Their Changing Roles from Alchemical Times to the Mid-Twentieth Century*.[39−41] Online initiatives such as Diversify Chemistry, Scientist Spotlights Initiative, and I Am A Scientist also provide a limited but growing source of biographies.[42−44]

Another important area of intervention is the textbook review process. New editions are typically sent out for review to a wide array of college/university faculty with a list of specific areas that should be addressed (e.g., coverage of concepts, chapter organization). In our experience as reviewers of college textbooks, neither of us have ever been asked to comment upon the gender parity or any other aspect of diversity or inclusion. Thus, asking about gender balance not only would improve the textbooks but also could help raise the collective consciousness within the discipline.

Textbooks, however, comprise only one component of the educational experience, so it is useful to consider the broader context for a college student aspiring to a STEMM career. For a STEMM student, the corridors and lecture halls are frequently adorned with images of famous scientists, known as "walls of fame" or "dude walls", that are predominantly, if not entirely, male.[45] The faculty members who teach their classes are disproportionately (80%) male.[33] Guest speakers, both those invited to campus and/or encountered at professional meetings, are predominantly male.[46] Thus, the STEMM educational landscape limits the available role models for female STEMM students, which fuels disengagement and attrition. Consequently, females remain a minority in STEMM professions, making it difficult to change inequitable practices, which further impacts the retention of females in STEMM. These structural practices, therefore, create a cycle that is self-reinforcing and will require directed effort to disrupt.

While the most obvious impact of gender bias in STEMM is on the opportunities, advancement, and inclusion of women,[47,48] gender bias also tarnishes the scientific community as a whole and impedes our ability to advance society. With such a conspicuous disciplinary bias, how can the scientific community expect to legitimately be viewed as objective? How can STEMM claim to be at the forefront of critical thinking when the accomplishments of women and the data that exposes this bias are ignored? Consequently, these issues can fuel the public's mistrust of the scientific enterprise and thereby further impede progress. It is time for scientists to reconcile with each other and the public it serves. We must eradicate bias in the sciences and replace it with an inclusive and innovative environment that will cradle new ideas and propel us to solve the complex issues facing the world today.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available at https://pubs.acs.org/doi/10.1021/acs.jchemed.0c01037.

Supplemental tables include image analysis of current US college-level general chemistry textbooks, a list of the females indexed in the textbooks, the number of named

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STEMM professionals and percentage of pages with names or named parameters in each text, a list of the male scientists included in all 10 general chemistry textbooks published between 2016 and 2020, and publisher information and number of named STEMM professionals in the indices of texts used in the temporal comparison (PDF, DOCX)

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Author Contributions

All authors contributed to this work and have approved the final version of the manuscript.

Notes

The authors declare no competing financial interest.

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