



Science Literacy and Text Book Biases

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Abstract

Textbooks are a common source of science information in K-12 science education. Science literacy is a major challenge of students in K-12 and this dramatically affects students' achievement. Biases in textbooks negatively influence students' interest and achievement in science and engineering.

This study explores types of biases in K-12 science texts. These biases primarily relate to gender, race and ethnicity. Textbook biases negatively affect students' views of science as a field, as a career and as a college major. Achievement may also be affected by such biases. Accordingly, this research study explores the biases in K-12 science textbooks. The textbooks were analyzed using a multidimensional rubric and accompanying scoring checklist. Results of these analyses revealed dramatic biases in textbooks particularly for early elementary and high school texts. Both print and photographic biases were noted in the textbooks. In particular, the books that focused on biological sciences were found to contain significant biases especially related to gender. These biases may influence how students feel about careers in science, technology, engineering and mathematics (STEM) areas and therefore may impact future workforces in STEM fields.

Introduction

Engineers and scientist utilize the principles and theories of science and mathematics to design, test, and manufacture products that are important to the future of our nation and the world.¹ The percentage of college students seeking degrees in math, science and engineering disciplines has been declining for the past two decades. This is in part because fewer potential science, technology, engineering, and mathematics (STEM) majors are completing rigorous college preparatory programs that would enable them to be accepted in undergraduate engineering programs after high school.² The number of people from racial and ethnic minority groups and women are especially sparsely represented in science and engineering fields. This shortfall has raised concerns among leaders in STEM fields regarding future STEM workforces.³

To meet the changing demands of the nation's science and engineering labor force, recognition of the importance of pre-college education and implementation of challenging curricula that captures and sustains students' interest and addresses their academic achievement in science and engineering is critical. Textbooks are a primary source of scientific information in K-12 science education. Science literacy is a major challenge of students in K-12 and this profoundly impacts students' achievement. Biases in textbooks negatively influence students' interest and achievement in science. This is of particular concern for women and underrepresented minority groups. When students are not represented positively and equitably in books, they are less interest in engaging with them and this limited engagement in turn leads to poor reading achievement.⁵ This is of particular concern in subject areas where content is challenging because difficult subjects require deep engagement with vocabulary and comprehension to fully understand the content. Essentially, if students are "turned off" by texts, they will disengage and learning will be compromised. This could be devastating for K-12 learners.

Content area literacy is particularly difficult for learners whose primary language is not English. The United States has the greatest number of minority students in the country whose primary language is not English (over 1.5 million, 25% of total school population). Ironically, these students are often most underrepresented in photos and graphics in K-12 science textbooks. Under No Child Left Behind⁶ schools must ensure that English learners (ELs) show significant yearly progress in developing English skills as well as meeting grade level standards in all academic content areas. According to the latest report card on the implementation of NCLB, schools are falling far short of meeting the academic needs of their English Learners.⁷ These students struggle to develop the cognitive academic language proficiency (CALP) necessary to comprehend content-area textbooks particularly in science. Chall, Jacobs, and Baldwin⁸ note that the breakdown in academic achievement in STEM content areas as particularly significant. Content-area texts contain a large number of content-specific vocabulary words and concepts that are beyond the students' English language abilities. Students need to be taught how to read content-area texts as well as to develop the academic language and discourse associated with each content area, particularly as they proceed through cognitively demanding curricula such as science. As such, if students are disengaged because they see that texts do not represent them equitably, their engagement and most importantly their achievement may suffer.⁵ In other words, textbook biases effect both engagement and achievement as it relates to literacy.

Research on textbook bias in general

Importantly, textbook bias is not a new area of research persay, as it has been studied for the past two decades. Unfortunately, much of this research has been conducted in early childhood education and has not addressed the scientific disciplines.^{9,10} Within studies of bias, research that investigates the presence of bias in textbooks focuses primarily on gender bias. Several scholars have undertaken a quantitative approach of analyzing the content of textbooks. Such studies provide a foundation for similar research, yet they are different from the present study, which has as its purpose to specifically identify the biases in science textbooks that may interfere with students' science interest and ultimately, their achievement in STEM disciplines.

Textbook biases in non-scientific subject areas

Various researchers have studied textbook biases disciplinarily. Peterson and Kroner¹¹ investigated the presence of gender bias in psychology and human development in university textbooks. These researchers developed two coding schemas to categorize the types of biases that they observed in the texts in their study; one that was used to analyze introductory psychology texts and the other that was used to analyze human development texts. The authors' research goals were to (a) develop a measurement tool for evaluating gender bias in textbooks, (b) to determine how much change had occurred since the American Psychological Association's guidelines for non-bias text had been issued, and (c) to evaluate the current level of equity of gender representation in texts. The researchers found gross inequity in gender representation in the textbooks that they analyzed. Women were often portrayed as "passive participants" rather than "active agents" in the texts. Peterson and Kroner also suggest several useful guidelines for creating more inclusive texts derived from a careful review of photos and character description in the texts. Similarly, Campbell and Schram¹² reviewed psychology and social science texts for gender bias. They searched for examples of "nonsexist" language and "profeminist" language.

Using both qualitative and quantitative analyses, Campbell and Schram¹² found results similar to Peterson and Kroner¹¹ illustrating that the reviewed texts included sexist language.

Bias in science textbooks

Garcia¹³ undertook one of only a handful studies that focused on racial bias in texts. He analyzed high school science texts for the presence of a “Hispanic perspective.” While the research is useful as it is one of the first studies to focus on Latina/o representation in science textbooks, the study is quite dated.

In a more recent and somewhat related study, Ndura¹⁴ investigated cultural bias in high school textbooks for the potential impact on English learners. Ndura analyzed texts by focusing on three important themes: (1) stereotyping, (2) invisibility, and (3) non-reality. Ndura argued that both teachers and students needed to be trained to analyze textbooks utilizing a critical lens as a means for addressing bias in classroom.¹⁴ As such, with this recommendation, even when stereotyping or invisibility occurs, students are able to dialogue about the problems in texts that they are reading, thus addressing biases head on, while making connections to larger social issues of biases. This study prescribed an intervention associated with confronting biases in texts in addition to an analysis of texts that may be applied in diverse K-12 settings.

Wilkinson¹⁵ undertook a quantitative analysis of physics textbooks for the emphasis on specific components of science literacy. The textbooks he analyzed were chosen from a twenty-year publication timeframe. Wilkinson wished to understand what particular content was emphasized in physics texts within four themes that had been previously used in other science text analyses: (a) knowledge of science, (b) the investigative nature of science, (c) science as a way of thinking, and (d) the interaction between science, technology, and society. Wilkinson adapted an instrument for his analyses that was previously designed to uncover text biases in other areas. The instrument utilized a checklist, which described the four themes. He found that all four thematic areas within the physics textbooks contained biases.

Eide and Heikkinen¹⁶ investigated the inclusion of multicultural material in middle school science teachers’ resource texts. Noting that teacher resource texts (often referred to as teachers’ editions) are highly used instructional resources, the authors analyzed the extent of multicultural content in twenty-one teachers’ editions of middle school science texts. The authors did not focus on illustrations and images in their analyses. Rather, they designed a systematic arrangement for classifying units of communication from the printed material in the texts and transformed the print quantitatively by assigning numeric codes to categories of content within text. They found that multicultural content was present in only small amounts in middle school teachers’ editions. This finding led Eide and Heikkinen¹⁶ to recommend additional inclusion of this important material in the science resource texts. They posited that it would be very difficult for teachers to teach multiculturally using their resource books given the sparse representation of this content.

Similarly, Delgado¹⁷ reviewed biology textbooks for the presence of multicultural science educational material. Delgado¹⁷ assessed the portrayal of minority groups, in both image and text, with an emphasis on “indigenous people” and “indigenous knowledge.” The results of this study

indicate that minority groups were often portrayed as undereducated. Delgado¹⁷ recognized a stark need for text rewrite in his study as the vocabulary presented in the texts that was examined were from dominant groups and not often representing the perspectives of indigenous groups.

As described in the review of the research above, significant gaps in the literature on textbook biases have been identified. The bulk of research on textbook bias utilized content analysis to uncover and empirically categorize instances of bias. Checklists and unsystematic analyses dominate this literature. Few studies have explored texts across broad grade levels with the intention of recognizing trends in textbook biases. Additionally, multidimensional rubrics have not been used to systematically and empirically analyze features of bias in texts. Such instruments are useful because they have potential to make results of bias analyses accessible for teachers, students, and parents who are interested in recognizing and addressing biases similarly as was described as an intervention by Ndura.¹⁴ Additionally, biases discussed in contemporary research most commonly identified gender at the exclusion of other types of biases including race, class, and sexual orientation. Accordingly, further analyses of textbooks must include attention to other groups that have been traditionally affected by bias in society and in education.

Research design and approach

The present study attempts to address some of the gaps in the research described above with particular attention to multiple types of biases in K-12 science textbooks across grade levels. Potential biases of focus in this study include gender, race and ethnicity in science texts in addition to socio-political biases. Each of these biases can negatively impact students' views of science as a field, as a career and as a college major. Accordingly, these biases have potential to limit options for future scientists and engineers. Additionally, as previously described, K-12 students' achievement may be impacted by such biases, so the need for their identification and alleviation is rather urgent. As such, the purpose of the present study is to identify the types and to determine the prevalence of biases in science textbooks across K-12 grade levels. Therefore, this study answers two important research questions:

- What are the nature and prevalence of biases in science textbooks in K-12 education?
- What types of text biases are present in the science disciplines and at what grade levels are they most prevalent?

The study employs anti-bias theory as a framework for the text analysis. Anti-bias theory builds upon the work of Ndura,¹⁴ Derman-Sparks and Hohensee,¹⁰ (described above) utilizing an activist approach in which one challenges prejudice or biases, links these biases to societal challenges, and proposes change for societal improvement. In this paper, an attempt is first made to identify the type and prevalence of textbook bias and then to propose recommendations for changes in practice to address the biases utilizing an anti-bias approach similar to that which is described in Ndura's research.

Instrumentation

This study employed a multidimensional scoring rubric with a checklist addressing each rubric dimension (listed below). The rubric facilitates both a granular and holistic investigation of

science textbook bias. The rubric includes four important dimensions that are aligned with anti-bias theory:

- Visual content bias: Visual content is important as science texts contain many visual images that are either photographic or graphic. These images can be analyzed for how underrepresented groups are presented or misrepresented.
- Written content bias: Written content bias refers to the way underrepresented groups are described or depicted in writing. Word choice and written language use is a necessary part of this bias dimension.
- Author's perspective bias: This bias dimension refers to the author's hidden message he/she is sending via the text.
- Omission as bias: The omission as bias dimension refers to when particular groups are omitted from texts as a means of exclusion of representation.

The multi-dimensional rubric is structured such that on one half of the rubric there is an element checklist aligned with the four dimensions of bias (described above) and on the second half there is a holistic scoring schema (using a 4-point scale). The four-point scoring schema utilizes a continuum to determine the "level" or prevalence of bias in each of the four analytical dimensions. Inclusion criteria with examples for each of the four points on the continuum are included in the textbook scoring rubric as a guide for determining where the particular element of bias is best represented in terms of "level."

Instrument validation

Group calibration techniques were used to determine the rubric's construct and content validity in addition to its internal consistence.¹⁸ As an initial rubric calibration procedure (recommended by Mark Wilson¹⁸ for sound measurement and in particular item response theory; IRT), raters were provided with examples of textbook bias that fit into the different dimensions and bias levels (1-4) and were asked to rate each example using the rubric independently. They were then asked to share their ratings and build consensus in their results as a means of calibrating the rubric. Examples were then rescored after discussion of the initial individual example ratings, and once an accurate and acceptable calibration (~.5 standard deviations from the mean) with the example biases was reached, the criteria on each dimension and level of the rubric was adjusted in accordance with the raters' calibration.

Data analyses

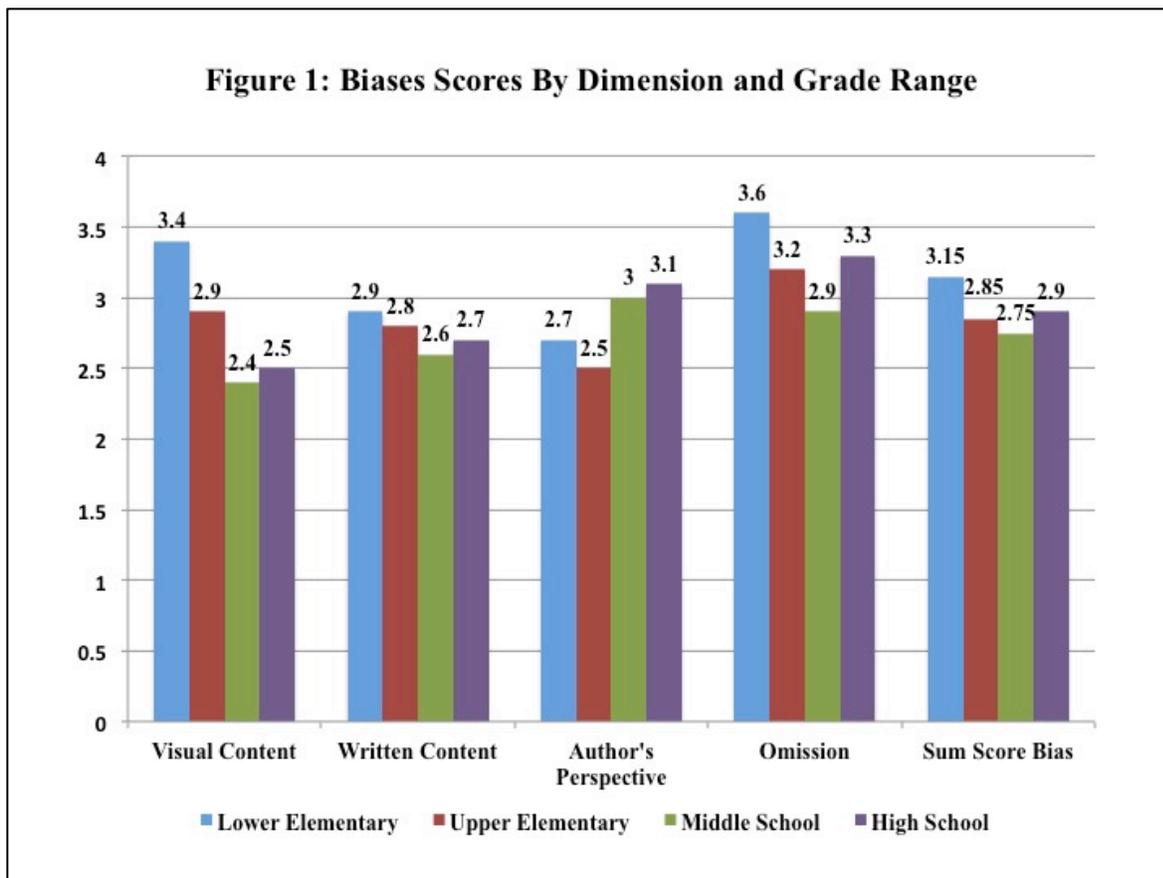
All textbook data (print, visual elements, etc.) was analyzed according to the four dimensions of the multi-dimensional scoring rubric (described above). Notes were taken on each on the rubric related to the dimensions for each analyzed text and these notes were categorized in accordance with the four dimensions to provide rationale for scoring on the rubric. In turn, the checklist portion of the rubric was used only to determine the existence of a particular type of bias within the four dimensions for which notes could be taken and categorized, thus forming evidence for scoring the text on each bias element in accordance with the rubric criteria.

Textbook selection

A total of forty-three science textbooks were analyzed for this study. Approximately 20% of the texts were used in elementary school (grades K-5), 20% were used in middle school (grades 6-8) and the remaining 60% of the texts were high school texts. The textbooks were chosen from a broad selection of science textbooks commonly used in three of the largest school districts in the western United States. Importantly, the greatest number of the analyzed books were high school texts because of the diverse subject areas within high school science. These included various advanced placement (AP) and honors science course textbooks.

Results of textbook analyses

Each of the forty-three analyzed texts were found to have biases in each of the four dimensions of the multi-dimensional scoring rubric to a lesser or greater degree. Figure 1 illustrates the distribution scores of the texts by rubric dimension and categorized by grade range. The ranges are divided as lower elementary (grades K-3), upper elementary (grades 4-5), middle school (grades 6-8) and high school (grades 9-12) to illustrate the range and prevalence of text biases.



The results of these analyses are interesting and diverse. The lower elementary texts had the greatest bias noted overall ($M=3.15$, $SD=.79$) followed by the high school texts ($M=2.9$, $SD=1.01$). In terms of the greatest bias prevalence, the dimension with greatest noted bias was that of omission of a traditionally underrepresented group, ($M=3.25$, $SD=.91$), although there was definitely a broad distribution across the four dimension of the rubric. These descriptive

findings indicate that much work needs to be done to equitably and accurately represent historically underrepresented students in science majors and careers in K-12 textbooks.

That which is not fully represented in the numeric values in the bias scores is the hidden messages behind the bias dimensions in the analyzed texts. Accordingly, examples of these biases are provided herein. The omission dimension is not possible to fully depict in this paper because omission, by definition refers to a group “not present” in the analyzed text. Omission typically was represented by underrepresentation of people of color and or women as scientists or engineers in the textbooks that were analyzed. Additionally, when inventors were discussed in the texts, historically underrepresented groups were omitted. To determine authors’ perspective in K-12 informational texts, it was important to review the backgrounds (educational and otherwise) of each of the contributing authors and editors and then to determine where and in what ways in the text that these backgrounds influenced the textbook message choices. This was somewhat different than that which is often found in a fictional text where authors’ voice is often overt.

Photos and illustrations (the visual dimension) were quite marked with biases in the science texts across grade ranges and science subject areas. These were especially prevalent in the life science, biology and physiology texts that were part of the study, where the study of human life and organisms were presented. However, even in non-life science type texts, bias was present in visual images within the textbook. Figure 2 (below) illustrates such bias.



Figure 2: Photo retrieved from a science text of a group of scientists conducting an experiment in which only men (and those who appear to be from dominant ethnic groups) appear in the photo.

In this photo, (Figure 2), one would note that only males were featured in this photo of a scientific experiment in progress. Not only are only men depicted in the photo (above), the photo does not represent any ethnic diversity. While at first glance one might think that this visual depiction the norm in the scientific world, if the desire is to “change the face” of science nationally and world-wide, one must not only be to sensitive to the hidden messages sent by textbook photos, one must also make deliberate efforts to diversify scientific images in texts in order to positively influence diversity in future science workforces.

Words in science textbooks often have as many hidden messages and meanings as visual images. They can present scientific history in a highly biased manner. This has most recently been portrayed in the following ways. A science textbook may feature a glossy pullout of female scientist, however include precious little text-based narrative of the scientific contributions of women. As an example of this, the following quote was uncovered during analysis of a middle school science text in the study: “Businessmen are now looking for entrepreneurial thinkers that can take the place of the traditions of the American scientist.” The word “men” in the first phrase of the sentence sets the stage for a gender-biased text excerpt. Indeed not all business people are males. Secondly, the statement is American-centric, as it refers to the traditions of American scientists, thus potentially setting up omission of contributions of non-American scientists.

While some may view these two examples as singular, these types of biases have been found via the present study to dominate K-12 science textbooks. Putting an end to such biases may contribute to building an anti-bias framework in K-12 STEM, thereby increasing equity in science fields long term.

Discussion, limitations, conclusions and future research

This research represents a starting point for exploring and ultimately ending both the negative influence of science text bias on academic achievement and decreased interest in science for girls and other underrepresented minority groups. The textbook biases present across the K-12 lifespan are quite alarming. This is especially evident in visual images and in the life science related subject areas. The finding that the greatest amount of bias was found in early elementary level textbooks is quite alarming because the message sent by informational texts to young children could have lasting adverse effects on the choices that they make career-wise. Additionally, this could affect our world’s most vulnerable children’s interest and motivation to read science texts, which could ultimately negatively impact their science literacy and achievement. This can inform the future of science and engineering fields.

To carry this research forward, future research should be conducted in which K-12 learners are interviewed as to their thoughts about representation and biases in science texts. Teachers should also become a part of such research to determine the impact that these texts have on teacher instruction and associated biases. Once these interviews are conducted, students and teachers from diverse groups should engage in exercises that explore the relationship of such biases to societal issues in broad scientific and engineering contexts. Solutions for ending such biases could be posed by K-12 learners, thereby providing content and context for anti-bias curricular reform in K-12 STEM education.

Additionally, research should be conducted that explores the relationship between textbook biases and science achievement longitudinally in students who have been historically underrepresented in the science fields. Finally, interventions should be developed in K-12 science classrooms in which students themselves analyze their texts for biases and use these identified biases as a means for activist projects that focus on confronting and changing biases in STEM fields. In that way these biases can be called out, discussed, and processed by those who may be most affected by them. Change can start on the grassroots level with the future of STEM workforces at the helm of curricular change.

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