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Sex and gender essentialism in textbooks

Several widely-used high school biology texts depart from established science

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Essentialism is the lay assumption that categories of living things have underlying, unobservable “essences” (1, 2). When applied to sex and gender, this assumption has a range of negative consequences, including stereotyping and discrimination (1, 2). Here, we investigate a potentially powerful—but so far unexamined—sociocultural influence on the development of essentialism about sex and gender: what high school biology textbooks teach adolescents about these topics. We content-analyze six of the most widely used textbooks in the US and find that they depart from established scientific knowledge about sex and gender, instead portraying these categories in a manner consistent with essentialism.

Three basic assumptions undergird the essentialist view of sex and gender (1): (a) there is little to no variation in traits or behaviors within a sex or gender group; (b) differences between sexes or genders are discrete—the groups do not overlap substantially in traits; and (c) internal factors such as genes are the best explanation for all forms of variation within and between sex or gender groups (Fig. 1). Scientific research on sex and gender is inconsistent with these assumptions (3, 4), yet they are commonly held. For example, substantial portions of US adults (~40-70%) attribute gender differences in traits and behaviors to genetic causes (5).

Theories suggest that essentialism of sex and gender develops through an interaction between general conceptual biases, such as an explanatory bias toward inherent causes (2, 6), and the social and cultural input to which children are exposed (2, 7). Here we investigate high school biology textbooks as a sociocultural source of essentialist ideas about sex and gender, one that may be particularly important given textbooks’ presumed scientific authority and considering that the vast majority of high school science classrooms in the US have designated textbooks that are used on a regular basis to guide instruction (8). In

addition, studies have linked biology textbooks to the development of essentialism about racial groups (9). Thus, examining if biology textbooks discuss sex and gender in ways that are consistent with essentialism is a valid means of improving our understanding of how essentialism develops during adolescence.

Of course, science textbooks often discuss ideas that were considered accurate earlier in the history of science and are now known to be incomplete or partially inaccurate, such as the Bohr model of the atom. Yet, essentialism is not a scientific model (10); it is a lay view (1, 2) that is at odds with the scientific consensus on sex and gender (3, 4). Thus, it should have no place in the biology curriculum.

THE SCIENCE OF SEX AND GENDER

Sexual reproduction generates new allelic combinations within a species (3). Sex determination is the process by which an organism develops a particular sex—the ability to produce a particular type of gamete, along with any associated phenotypic traits. This process is tremendously variable across species. In some species (e.g., cichlid fish), an individual’s sex can be determined by the temperature of their physical surroundings and can reverse. Some species have more than two sexes (e.g., some fungi have thousands); others have more than two sex chromosomes (e.g., the platypus has 10) or sex chromosomes other than X and Y (e.g., birds have Z and W sex chromosomes).

Considerable complexity is present among humans as well. In fact, because so many biological mechanisms are involved in sex determination, biologists now understand human sexes to be complex phenotypes that emerge through interactions between genes, including the sex-determining SRY gene on the Y chromosome and a range of hormone-encoding genes (e.g., SOX9, SF1, WNT4), and the environment inside and outside the body (e.g., via epigenetic regulation) (3). As a result of this complexity, human sex variation is not strictly dichotomous at the biological level; rather, it is best described as a somewhat continuous, bimodal distribution (3). This biological variation intersects with the cultural practices of

medical clinicians to influence sex assignment (3), often in ways that reduce the underlying biological complexity to a simpler binary: females and males. However, many intersex humans exist who blur the hard lines between males and females (3).

Further blurring these lines, most phenotypic traits associated with sex categories are the products of complex gene-environment interactions that give rise to vast continuous variability among individuals of the same sex, and, conversely, substantial overlap between individuals of different sexes. For instance, human sexes have similar patterns of gene expression and heritability for many complex traits (11), including brain morphology (12), physical traits (3), and disease severity (3). Notable exceptions to this pattern of between-sex similarity are traits such as menstruation, which only occurs among egg-producing females. Altogether, nearly all trait variation that exists within and between human sexes is not what essentialism predicts, and neither is the causal source of this variation (that is, there are no genetic “essences”) (Fig. 1).

The same arguments apply to gender, perhaps even more forcefully, since gender is a socially constructed lay interpretation of the biological phenomenon of sex (3, 4). Individuals who identify as women or girls are often expected to adopt a set of socially and culturally prescribed activities, abilities, and interests that distinguish them from individuals who identify as men or boys (3, 4). Thus, differences in complex traits (such as activities, abilities, and interests) between individuals who identify as different genders have no biological basis and are instead explained by sociocultural factors (4). Notably, despite social expectations for distinct gender attributes, complex traits vary substantially and continuously within each gender and have distributions that are highly overlapping across genders (4). Thus, the predictions of essentialism are incorrect about gender as well (Fig. 1).

Although sex (a biological phenomenon) and gender (a sociocultural phenomenon) are carefully distinguished among biologists who study these phenomena (3), this distinction is often absent in public discourse, where sex and gender are

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typically conflated. If biology textbooks also conflate the two phenomena, they would be giving voice and lending authority to an uninformed lay view that is out of step with well-established scientific knowledge.

TEXTBOOK ANALYSIS

We aimed to identify a sample of high school biology textbooks that are widely used across the US. A challenge is that textbook manufacturers do not publish statistics on how many schools or students use their textbooks. Thus, we instead used information found on the websites of state and county boards of education to identify textbooks adopted in at least two of the following states: California, Texas, New York, and Florida. Because these states are the most populous in the US, they strongly influence which textbooks are adopted throughout the US (13). This process (described more fully in the supplementary materials (SM)), identified six textbooks published between 2009 and 2016. We estimate that collectively these textbooks are used by 66% of introductory high school biology classes across the US (14).

Out of a total of 216 chapters across the six textbooks, 10 chapters fit the criteria for inclusion: They were genetics chapters that discussed sex or gender. Next, we identified 362 paragraphs in these 10 chapters that included mention of sex or gender terminology. Our analyses focused on these paragraphs (see SM for details about coding)(see textbox for examples of textbook passages and coding).

Sex and gender

We initially attempted to make a systematic distinction between terms that pertained to sex (e.g., “Y chromosome”) and terms that pertained to gender (e.g., “men”). However, it quickly became clear that this would not be feasible. The information available in the textbooks was not sufficient to make this distinction (see SM). This blurring of the linguistic boundary between sex and gender suggests in and of itself that textbooks may conflate the two. Going forward, we use the term “sex/gender” when appropriate to describe our results.

Despite the imprecision in how sex and gender terminology was used, we were able to code whether sex and gender were explicitly differentiated in a paragraph. Of the 362 paragraphs coded, none differentiated between sex and gender in any way. Thus, textbooks inappropriately conflate between a biological phenomenon

(sex) and a sociocultural phenomenon (gender).

Variation within sex/gender groups

People who hold essentialist beliefs tend to believe that individuals within a sex/gender group are uniform (i.e., no variation) or differ by type (i.e., little variation) (1, 2). In contrast, the reality is that most traits are multifactorial and thus vary continuously within sex/gender groups (3, 4). We coded for how often members of the same sex/gender group were described as (a) uniform (i.e., not differing at all), (b) differing by type (e.g., women with blue eyes vs. brown eyes), or (c) differing in a continuous way (see Table S3).

12% of paragraphs described individuals of a single sex/gender group as uniform ($\beta = 0.12$, 95% CI [0.08, 0.17]; see SM for analytic strategy). In addition, 10% of paragraphs described individuals of a single sex/gender group as differing by type ($\beta = 0.10$, 95% CI [0.05, 0.16]). In contrast, descriptions of continuous variation within a sex/gender group occurred in only 3% of paragraphs ($\beta = 0.03$, 95% CI [0.01, 0.05]). There was no significant difference between the code proportions indicating uniformity and differences by type ($\beta = 0.02$, 95% CI [-0.03, 0.06]). Both of these codes were more common than the code indicating continuous variation ($\beta = -0.10$, 95% CI [-0.15, -0.04], and $\beta = -0.08$, 95% CI [-0.14, -0.02], respectively).

These findings indicate that textbooks under-emphasize the vast amount of continuous variability within sex/gender groups that has been documented by biological research, and instead convey that individuals within such groups are relatively homogenous, which is an idea that is consistent with essentialism.

Variation between sex/gender groups

People who hold essentialist beliefs tend to believe that sex/gender groups are mutually exclusive—that members of one group are entirely dissimilar from those in another group (1, 2). In contrast, the reality is that most traits overlap considerably across sex/gender groups (3, 4). We coded for how often sex/gender groups were described as (a) categorically different or (b) similar or overlapping (see Table S3).

16% of paragraphs described categorical differences between sex/gender groups ($\beta = 0.16$, 95% CI [0.10, 0.22]). In contrast, only 11% of paragraphs described similarities or overlaps across sex/gender groups ($\beta = 0.11$, 95% CI [0.06, 0.16]). The difference between these code proportions was not statistically

significant ($\beta = 0.05$, 95% CI [-0.01, 0.11]). Yet, because sex/gender groups overlap considerably on most complex traits (3, 4), even this seemingly balanced presentation of similarities and categorical differences is more consistent with essentialism than with the scientific consensus on sex and gender.

An ancillary analysis also revealed that textbooks never mentioned the phenomenon of intersex. By doing so, textbooks again departed from scientific reality and presented an exaggerated picture of sex/gender differences, consistent with essentialism.

Internal vs. external explanations

People who hold essentialist beliefs tend to believe that variation within and between sex/gender groups is the product of a single internal factor, such as a gene or a hormone, or multiple internal factors (e.g., alleles) that are inherited together through a sex chromosome (1, 2). In contrast, the reality is that most differences between humans, especially in complex traits and behaviors, cannot be reduced to internal factors alone (3, 4). We coded the explanations in the textbooks as (a) internal (i.e., appealing to factors originating inside the body, such as genes) vs. (b) external (i.e., appealing to factors originating from outside the body, such as the environment; see Table S3).

Internal explanations were given in 12% of paragraphs ($\beta = 0.12$, 95% CI [0.06, 0.20]). External explanations were given in only 1% of paragraphs ($\beta = 0.01$, 95% CI [0.003, 0.02]). This difference was statistically significant ($\beta = 0.11$, 95% CI [0.05, 0.19]).

In an ancillary analysis, we coded for the number of causes mentioned in an explanation: single vs. multiple. We found no difference in the prevalence of single- and multiple-cause explanations (see SM).

Alternative interpretation?

We interpreted the evidence above as suggesting that textbooks convey essentialist messages about sex/gender. However, perhaps most of the essentialist descriptions that we identified in our coding (e.g., within-group uniformity) concerned the small set of traits involved in human sex differentiation, such as reproductive organs. At a somewhat superficial first glance that ignores the biological complexity of human sex differentiation, this subset of traits are relatively uniform within a sex, discrete between sexes, and explainable by internal causes. Our claim that textbooks are conveying unscientific views would be weakened if the descriptions we labeled “essentialist” were

applied predominantly to this subset of traits. To investigate this alternative interpretation, we tested whether essentialist (vs. anti-essentialist) descriptions were more strongly associated with the traits that are integral to sex differentiation vs. other (e.g., cognitive, behavioral) traits. We found no evidence that this was the case (see SM), consistent with our claim that textbooks are conveying essentialist messages about sex and gender.

DISCUSSION

When describing sex/gender groups as uniform, or as composed of different types, biology textbooks are expressing essentialist views that are inconsistent with scientific reality: It is continuous variation that is the norm within sex and gender groups. When describing between-group variation, biology textbooks discuss differences and similarities at similar rates. In actuality, sex and gender groups overlap substantially on most complex traits (3, 4). Rather than reflecting this reality, textbooks paint a picture consistent with the essentialist notion that sex and gender groups are discrete.

When explaining the patterns of variation within and between sex/gender groups, textbooks are far more likely to use internal factors than external factors. On the one hand, this may seem unsurprising: The texts in our sample were communicating the science of genetics, and genes are located inside our bodies. On the other hand, most variation within and between sex and gender groups is not reducible to genes alone (3, 4). For instance, most human sex differences involve complex phenotypic traits, which are best explained through multifactorial models that take into account environmental factors and gene-environment interactions (3). In addition, because gender roles are socially constructed, environmental factors rather than genes account for gender differences (e.g., activities, abilities, interests). Rather than communicate this complexity, the textbooks instead suggested that variation in one or more genes inherited through the sex chromosomes was the only viable explanation for variation within and between sex/gender groups—an essentialist perspective.

One limitation of our study is that we did not search for sex and gender terms outside of genetics chapters. We may have thus under-identified messages that are inconsistent with essentialism about sex and gender. However, qualitative studies that have analyzed the non-genetics chapters of biology textbooks using the lenses of feminist and queer theory—which were developed to uncover and counter

gender essentialism—do not support this optimistic view (15).

It is noteworthy that the four US states from which we sampled the textbooks differ in political orientation. Textbook content is strongly influenced by cultural and political struggles, especially when it comes to dimensions such as sex and gender. Yet, the variability in code frequencies across our sample of textbooks was close to zero (see SM), meaning that our textbooks were remarkably isomorphic in how they discussed sex/gender. This reinforces the claim that our statistical inferences are generalizable to the broader population of US biology textbooks. However, our data cannot speak to whether the same patterns would be observed in other countries' textbooks.

Biology education has long been criticized for presenting an oversimplified view of genetic inheritance (9). A salient example of this is the failure to communicate that genetics is more complicated than the inheritance patterns that Gregor Mendel produced using 19th century pea varieties (9). In fact, Mendelian traits that segregate in an either/or way because of variation in a single gene are the exception to the rule when it comes to the panoply of ways in which humans differ from one another (3). The present results highlight another important way in which biology education falls short, and one with implications for young people's fundamental beliefs about sex and gender. Indeed, prior research has found that passages from business-as-usual biology textbooks can reinforce gender essentialism in students (10).

More optimistically, the present results also suggest how textbooks could be changed to avoid these undesirable consequences. Since textbook content strongly influences what is taught in science classrooms (8), changing how textbooks describe and explain sex and gender variation could yield a broad decrease in gender essentialist beliefs among US adolescents.

We highlight several aspects of current textbooks that could be revised. First, textbooks can define and differentiate the concepts of sex and gender, just as biologists do (3). Then, when discussing sex, textbooks can explain that sex determination in many species (humans included) is complex, involving multiple genetic, hormonal, and environmental factors (3). For example, including the phenomenon of intersex would highlight the complexity of human sex variation. Textbooks can also communicate that there is a tremendous amount of (continuous) variability within individuals of the same sex or gender and that individuals belonging to different sex

or gender groups overlap substantially on complex traits. Finally, and perhaps most crucially, textbooks can communicate that the traits that are stereotypically associated with a sex or gender group cannot be explained by genes alone—the story is far more complicated.

REFERENCES AND NOTES

1. I. Dar-Nimrod, S. J. Heine, *Psychol. Bull.* **137**, 800–818 (2011).
2. S. A. Gelman, *The Essential Child: Origins of Essentialism in Everyday Thought*: Oxford University Press (2003).
3. E. A. Khramtsova, L. K. Davis, B. E. Stranger, *Nat. Rev. Genet.* **20**, 173–190 (2019).
4. T. E. Charlesworth, M. R. Banaji, *J. Neurosci.* **39**, 7228–7243 (2019).
5. E. R. Cole, T. E. Jayaratne, L. A. Cecchi, M. Feldbaum, E. M. Petty, *Sex Roles*. **57**, 211–222 (2007).
6. A. Cimpian, E. Salomon, *Behav. Brain Sci.* **37**, 461–480 (2014).
7. M. Rhodes, T. M. Mandalaywala, *WIREs Cogn. Sci.* **8**, e1437 (2017).
8. E. R. Banilower *et al.*, "Report of the 2018 NSSME+" (Horizon Research, Inc., Chapel Hill: NC, 2018), p. 442.
9. B. M. Donovan, *Hum. Genet. Genomics Adv.* **3**, 1–13 (2021).
10. B. M. Donovan, M. Stuhlsatz, D. C. Edelson, Z. Buck Bracey, *Sci. Educ.*, 1–31 (2019).
11. S. M. Smith *et al.*, *Nat. Neurosci.* **24**, 737–745 (2021).
12. D. Joel *et al.*, *Proc. Natl. Acad. Sci.* **112**, 15468–15473 (2015).
13. M. G. Watt, *Int. Assoc. Res. Textb. Educ. Media E-J.* (2009).
14. B. M. Donovan *et al.*, *data and code* https://osf.io/deqj3/?view_only=6052aedf895c4b8bbeb0f95f1d8d1e68.
15. V. L. Snyder, F. S. Broadway, *J. Res. Sci. Teach.* **41**, 617–636 (2004).

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Supplementary material
URL

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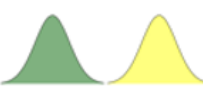
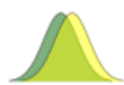
	Within-Group Variation	Between-Group Variation	Explanation for Variation		
Essentialism	 Within-group uniformity	 Between-group differences	 Genes		
Science	 Within-group heterogeneity	 Between-group similarities	Within-Group Variation		
			 Genes	 Environment	
			Between-Group Variation		
			Between Sexes  Genes	Between Genders  Environment	 Environment

Fig. 1. Essentialist and scientific perspectives on sex and gender. Essentialism assumes uniformity within sex and gender groups in complex traits; science reveals within-group heterogeneity. Essentialism assumes that sex and gender groups are non-overlapping; science reveals substantial overlap. Essentialism assumes that genes explain any within- and between-group variation; science reveals that the environment and gene-environment interactions are the best explanations.