5-2021

The peacock in the room: confronting the hidden curriculum of androcentrism and gender bias in undergraduate biology education.

Sarah Hamilton Spaulding
University of Louisville

THE PEACOCK IN THE ROOM: CONFRONTING THE HIDDEN CURRICULUM OF ANDROCENTRISM AND GENDER BIAS IN UNDERGRADUATE BIOLOGY EDUCATION

By

Sarah Hamilton Spaulding
B.S., Northern Kentucky University, 2012
M.S., University of Kentucky, 2015
M.S., University of Louisville, 2018

A Dissertation Submitted to the Faculty of the College of Arts and Sciences of the University of Louisville in Partial Fulfillment of the Requirements for the Degree of

Doctor of Philosophy in Biology

Department of Biology
University of Louisville
Louisville, Kentucky

May 2021

THE PEACOCK IN THE ROOM: CONFRONTING THE HIDDEN CURRICULUM OF ANDROCENTRISM AND GENDER BIAS IN UNDERGRADUATE BIOLOGY EDUCATION

By

Sarah Hamilton Spaulding

A Dissertation Approved on

April 14, 2021

By the following Dissertation Committee

Dissertation Chair

Dr. Linda Fuselier

Committee member

Dr. Perri Eason

Committee member

Dr. Kasi Jackson

Committee member

Dr. Justin McFadden

Committee member

Dr. Michael Perlin

DEDICATION

This dissertation is dedicated to my children

Lily, Rowan, and Cora.

Acknowledgements

I would like to thank Dr Linda Fuselier, except "thanks" seems insufficient a sentiment to describe my overwhelming gratitude for the privilege of her mentorship. She provided just the right amount of guidance, wit, humor, warmth, leeway, and instruction to facilitate my development into something more than what I was before. Would that all graduate students were as fortunate as I have been in this respect. I would also like to thank the members of my committee for their feedback and assistance over the past few years. Thanks to my friends who have provided both encouragement and extracurricular distractions, and to my family who manifested my existence and helped shape me into the human I have become. Finally, I would like to thank my husband, Rob, who held our family together as I descended into dissertation-induced madness.

ABSTRACT

THE PEACOCK IN THE ROOM: CONFRONTING THE HIDDEN CURRICULUM OF ANDROCENTRISM AND GENDER BIAS IN UNDERGRADUATE BIOLOGY EDUCATION

Sarah Hamilton Spaulding

April 14, 2021

This dissertation exposes one manifestation of the hidden curriculum of gender bias in the biological academe and explores the impacts of implicit essentialist perspectives on biology curricula and student understanding of an important evolutionary concept. Chapter one introduces the concept of gender essentialism and its relationship to the hidden curriculum of gender bias. I conclude the introductory chapter by reviewing tenets from queer curriculum theory and suggesting that applications of the theory may provide educators with the pedagogical tools required to counter implicit essentialist perspectives.

Chapter two describes a textbook image analysis informed by previous textbook analyses to examine the visual presentation of sex roles in current undergraduate Animal Behavior textbooks and an 11-edition series. I found that most textbook images failed to highlight the significant shift in the scientific community’s understanding of animal sex roles in recent decades by highlighting classic sex roles through a lens of androcentrism. Communicating tacit gender essentialism and bias through sex stereotypic images in

biology textbooks risks the perpetuation of scientifically inaccurate, determinist dichotomies that function to disenfranchise women from societal and scientific endeavors and thus inspired the studies detailed in chapters three and four.

Chapter three describes a photo-elicitation study in which undergraduate students were asked to describe images similar to those they would encounter in the chapters of biology textbooks covering sexual selection theory. I found that students consistently include anthropomorphisms and human gender stereotypes in their descriptions of non-human animals, and that student perceptions of animal behaviors were influenced by a number of factors, including the context provided, the taxa depicted, and levels of existing implicit bias.

Finally, chapter four examines the relationship between student essentialist perspectives and their understanding of sexual selection theory. Results from this study indicate that strong essentialist perspectives may impede student understanding of sexual selection concepts that highlight variation and flexibility, and that some students benefit from being presented with a more complex view of the theory. Collectively, the works detailed in this dissertation expose the hidden curriculum of gender essentialism in biology education and highlight an opportunity for science educators to facilitate an inclusive discourse that interrupts the perpetuation of harmful gender stereotypes.

TABLE OF CONTENTS

LIST OF TABLES PAGE

LIST OF FIGURES PAGE

CHAPTER ONE

EXPOSING THE HIDDEN CURRICULUM OF GENDER ESSENTIALISM IN BIOLOGY

GENDER ESSENTIALISM

Within evolutionary biology, the tenets of sexual selection have been employed in the effort to better understand *sex roles* — that is, collective patterns of behavior between individuals engaged in competition for mating opportunities, exerting mate choice, providing parental care, and other behaviors centered around reproductive ecology (Ah-King & Ahnesjö, 2013). However, the concept of biological sex roles has been criticized for promoting a heteronormative narrative which fails to adequately reflect the flexibility and natural variation documented in the reproductive behaviors of male and female animals. Recently, studies have shown that scientific explanations of non-human animal sex roles often communicate an implicit and authoritative endorsement of gender essentialist perspectives by ascribing anthropomorphic gendered societal norms and values to the motivations and interactions non-human species (Ewald, 2016; Fuselier et al., 2018).

In humans, the endorsement of *traditional* sex roles has relegated women to the status of weak and passive caregivers while elevating men to the status of powerful and active providers (Larsen & Long, 1988). Although one's support of traditional versus egalitarian sex roles depends on a variety of factors (e.g., demographic and personality dimensions), studies have shown that, in general, men and conservatives have more traditional beliefs about sex roles while women and liberals have more egalitarian beliefs (Dunn, 1979; Marke & Gottfries, 1979). Combined with the historical exclusion of women from scientific endeavors, these factors have both encouraged an implicit scientific endorsement of gendered differences in personality and behavior and have influenced what questions are asked and how science is done (Ah-King & Ahnesjö, 2013).

THE HIDDEN CURRICULUM

Given that the enculturation of gender-appropriate behaviors often begins early in the home and is reinforced throughout one's education and occupancy in the labor force, it is, perhaps, unsurprising that cultural attitudes about sex roles emerge in youth and increase over one's lifetime (Reis & Wright, 1982). Individuals who come to believe that gender is a function of biology rather than a social human construct tend to hold stronger gender stereotypes and are more likely to self-stereotype than individuals who believe that gender is shaped by sociocultural forces (Heyman & Giles, 2006; Coleman & Hong 2008). Because essentialist perspectives are linked to distinct sociopolitical attitudes and firm, in-group boundaries that promote a multitude of unfavorable ideations (Keller, 2005), it is crucial that educators — who often spend as much time with a student as a student's biological family does — use their platform and authority to inculcate a narrative of equity and fluidity in discourse production.

And yet, despite remarkable changes in curriculum and pedagogy stemming from laws drafted in the 1970s geared towards eliminating sex stereotyping and discrimination, a hidden curriculum of gender bias remains ubiquitous at all levels of education and the true integration of women has yet to occur (Koch, 2003). As students progress in their education, they are inundated with implicit messages that perpetuate gender segregation and reinforce gendered behaviors (Koch, 2003; Thorne, 1993). Harmful gendered classroom dynamics (e.g., the preferential treatment of white male students; see Sleeter & Grant, 1985, and Ross & Jackson, 1991) and the gendering of academic interests by educators have been shown to induce stereotype threat (e.g., Inzlicht & Ben-Zeev, 2000; Cohen et al., 2000), and undoubtedly influence the disproportionate funneling of men into disciplines such as math and engineering and women into arts, humanities, and the social sciences.

QUEER CURRICULUM THEORY

Queer curriculum theory [QCT] promotes the examination of pedagogical scholarship through the lens of feminist and queer theories and endeavors to raise awareness of biased and value-laden practices within academia that privilege a normative and heteromasculine paradigm (Sumara & Davis, 1999). QCT encourages discourse that questions the perception of sex roles as fixed categories by endorsing a more fluid concept of gender and sexuality that enriches our understanding of human diversity. As such, it is a useful framework for the consideration of how human gender stereotypes emerge in biology curricula, a discipline in which women are less likely to advance professionally than in fields like physics, where the percentage of women is much lower (NRC, 2010).

Over the next three chapters, I detail several studies in which I consider the presentation of sex roles in biology curricula through the lens of QCT and how this may affect student conceptualization of sexual selection. The findings from my work suggest that using QCT as a framework may provide educators with a rewarding methodology for communicating a biological phenomenology that encourages diversity through inclusivity and objectivity.

CHAPTER TWO

NO CHANGE OVER TIME: PERSISTENT ANDROCENTRISM AND GENDER BIAS IN UNDERGRADUATE ANIMAL BEHAVIOR TEXTBOOKS

INTRODUCTION

IMAGES COMMUNICATE

Textbooks are important pedagogical tools used by educators to frame and communicate relevant disciplinary knowledge to students (Hogben & Waterman, 1997; Sánchez & Belmar, 2006). Educators rely heavily on textbooks and supplemental aids (e.g., slides, outlines, etc.) to inform and structure their curriculum, and students rely on textbooks as a tool for mastery (Sadker & Zittleman, 2007). Simultaneously, the content presented in textbooks reflects not only the social and historical contexts in which they are developed (Ferguson et al., 2006) but also the author's perception of what knowledge is relevant to the discipline. Disciplinary authorities are subject to influence by the social, personal, and historic milieu in which their expertise is acquired and maintained (Ford, 2008) and — perhaps, as a result — textbooks can be slow to assimilate new information antithetical to established disciplinary paradigms (Metoyer & Rust, 2011; Fuselier et al., 2016; 2018). When viewed from this perspective, textbooks scaffold the discourse of academic enculturation by shaping the content and framing information presented to novices by disciplinary experts and educators (Prior & Bilbro, 2012).

Over time, the inclusion of images (e.g., diagrams, photographs, illustrations, etc.) to aid in both the depiction of complex topics and the emphasis of important concepts has increased as printing and publication of these images has become easier. More so than the typed print, images in textbooks capture attention, carry meaning, evoke emotion and have been shown to improve student learning (Carney & Levin, 2002; Myers, 1988). Images send influential and lasting messages but, even photographs, are not unbiased documentation of the world (Prosser & Schwartz, 1998). This is significant, as [1] the images included in textbooks are considered to be visual depictions of claims to knowledge, and [2] students typically lack the "visual literacy" necessary to recognize and counter implicit social messages or biases that may be communicated in this manner (Bowen & Roth, 2002; Pauwels, 2008).

In fact, the perpetuation of a *hidden curriculum* (Stromquist et al., 1998) of gender bias is reinforced through textbook material. Among images of humans, patterns of androcentric bias and sex/gender stereotypes are depicted by the images in college textbooks spanning multiple academic disciplines. For example, men and women are often shown in gender stereotypical roles (Parker et al., 2017), and men are visually depicted as the anatomical norm (Lawrence & Bendixen, 1992), are pictured more often than women (Damschen et al., 2005; Hogben & Waterman, 1997; Parker et al., 2017), and are presented in more active roles and dominant status positions than women (Gullicks et al., 2005; Hogben & Waterman, 1997; Metoyer & Rust, 2011; Moore & Clarke, 1995; Peterson & Kroner, 1992).

Biology textbooks pose a particular risk for encouraging sex biases through implicit endorsements of biological determinism and gender essentialism. Determinism explains patterns of behavior as a function of biology and is the scaffold upon which gender essentialist attitudes are constructed (Ahnesjö et al., 2020; Haslam et al., 2002); essentialism depicts human gender roles as immutable, dichotomous, and the result of chromosomes and hormones (Amato & Booth, 1995; Klysing, 2020; Kray et al., 2017). However, the veracity of sex as a legitimate, dichotomous, and biological category has long been criticized: many physiological and behavioral traits considered to be dichotomous markers of maleness or femaleness may occur simultaneously within individuals or change over time, and neither "sex" nor "gender" are fixed traits that can be measured by a single, validated approach (Fausto-Sterling, 2019).

Recently, Fuselier et al. (2018) found that the images of non-human animals presented in Evolution textbooks also depict a strong androcentric bias. In fact, the typical visual presentation of sex roles in Evolution textbooks is rife with potentially influential negative sex/gender stereotypes that offer an implicit endorsement of biological essentialism by emphasizing stereotypic sex roles while failing to depict the variable and complex nature of reproductive interactions documented in the literature (Fuselier et al., 2018). The intrusion of human gender stereotypes into visual depictions of animal behavior is both revealing and problematic. It both elucidates the epistemic commitments and convictions of disciplinary experts charged with the construction and presentation of knowledge and risks the perpetuation of unfavorable sociopolitical ideations and implicit biases with an endorsement of strict sex/gender stereotypes (Keller, 2005).

Sexual selection theory

The topic of sexual selection offers educators an opportunity to highlight the social nature of knowledge production within a scientific discipline, and a scientific community's response to interdisciplinary critique. Sexual selection is a force of evolution in which the fitness of an organism depends on its ability to successfully attract and mate with individuals of the opposite sex (Darwin, 1871). The theory originated from Darwin's attempt to explain apparently maladaptive characteristics in animals (e.g., the beautiful but burdensome tailfeathers of male peafowl), and is tied to understanding "sex roles" related to competition for mating opportunities, mate choice, and parental care. Essentially, organisms undergo sexual selection when trait variants result in differential success within affiliative interactions (e.g., different-sex attraction) and/or agonistic interactions (e.g., same-sex competition).

Despite a modern near-paradigmatic acceptance writ large within much of the current scientific community, Darwin's original conception of sexual selection was criticized almost immediately after he proposed the theory, both for its androcentric and stereotypic assumptions about sex roles (Blackwell, 1875; Gamble, 1893) and the agency conferred to females via the radical notion of female choice (Cronin, 1993; Vandermassen et al., 2005). Following decades of neglect, renewed interest in the theory in the 20th century produced several tenants which now characterize the *classic* Darwin-Bateman sexual selection paradigm (Dewsberry, 2005): that is, [1] for males, *but generally not females*, a positive relationship exists between an individual's reproductive success and the number of mates it acquires and as such, sexual selection acts mainly on males through intersexual and intrasexual selection pressure (Bateman, 1948); and [2] males — by virtue of their small, inexpensive sperm relative to the large, expensive eggs produced by females — can afford to mate multiply and will exhibit high reproductive success as they compete with other males for access to females, whereas females are *de facto* choosier about their mates because they invest more energy into reproduction than males and, as a consequence, exhibit much lower variation in reproductive success (Emlen & Oring, 1977; Trivers, 1974).

Supporters of the classic paradigm argue that this sex-dimorphic investment of energy has resulted in behavioral and morphological differences between the sexes — that is, different sex roles. However, there are numerous examples of species that exhibit behaviors antithetical to the classic paradigm, and a recent literature review highlighted a wide variety of animal taxa which complicate early assumptions about sex roles (Tang-Martinez, 2016). For example, the identification of monogamous pair bonds in some species of lizards (Bull, 2000), and the overwhelming occurrence of polyandry (i.e., females mating multiply) among insects (Arnqvist & Nilsson, 2000). And yet, the determinist and androcentric biases which scaffold the classic paradigm persist.

Concerns have long been raised with the theoretical assumptions and methodologies employed during the seminal investigations of relevant phenomena (Altmann, 1974; Hubbard, 1988; Rowell, 1967; Snyder & Gowaty, 2007). Other critics have noted that problematic social and cultural influences are manifest in the use of anthropomorphic and gendered language (e.g., “coy,” “rape,” “homosexual”) used to describe the reproductive interactions and motivations of *active* male and *reactive* female non-human animals (Dougherty et al., 2013; Karlsson Green & Madjidian, 2011). In fact, even the validity of “sex roles” as a concept has been criticized for its implication of normative, binary, and sex-stereotypic expectations regarding the behaviors of males and females (Ah-King & Ahnesjö, 2013). Other scholars have even challenged the definition of sexual selection, which Roughgarden (2012) argues is, in fact, a subset of *social* selection in which the resource for which individuals are competing is mates.

Objective scientific knowledge

I adopted critical contextual empiricism (CCE; Longino, 2002) as a guiding theoretical framework for my investigation of the depiction of sex roles in Animal Behavior textbooks. CCE encourages the production of more objective knowledge through the consideration and accommodation of criticisms from diverse perspectives. Longino (2002) argues that the production of knowledge is a social and collaborative effort, and that communities invested in the production of objective knowledge offer mechanisms by which the claims put forth by disciplinary experts may be evaluated and critiqued for revision by qualified intellectual peers. In fact, the very integrity of scientific claims depends on the iterative and communal nature of science knowledge production, for example, vis-à-vis peer review from diverse perspectives (Longino, 2002; Ford, 2008). Phenomena for which scientists endeavor to devise explanations are framed, measured, and represented by individuals holding *a priori* assumptions — both explicit and implicit — which inform their choice of questions, hypotheses, methodology and interpretations. In other words, it is the community of scientific experts who collect and interpret data, and subsequently present findings to others for critique, who ultimately determine what knowledge is scientific knowledge. As such, the different experiences and assumptions of individuals about what constitutes reliable knowledge within a community bias both the production and presentation of disciplinary knowledge.

Consideration of how human gender stereotypes are perpetuated in biology curricula is both timely and important, as biased depictions risk contributing to the disenfranchisement of women in both society and scientific endeavors. For example, previous studies examining the effects of gender stereotypic images found that the internalization of these biases [1] affects women's academic performance (Davies & Spencer, 2005; Good et al., 2010), [2] influences how students assess their own performance and that of their peers (Steele, 1997), and [3] affects the assessment of women scientists throughout the trajectory of their careers (Davies & Spencer, 2005; Moss-Racusin et al., 2012, 2015). Although most images in Biology textbooks depict non-human animals, I argue that the propensity of young adults to anthropomorphize non-human animal images (Harrison & Hall, 2010; Morris et al., 2000) suggests these images may be equally effective at communicating implicit biases of a scientific community as are images of humans in textbooks from other disciplines. Thus, in addition to enriching our understanding of sexual selection, the interdisciplinary scholarly critique to which the theory has been subjected provides an opportunity to examine disciplinary commitments as communicated in textbooks through the lens of CCE.

METHODS

Previously, Fuselier et al. (2018) analyzed the visual depiction of animal sex roles in Evolution textbooks; however, Animal Behavior textbooks, given their specialized focus, cover more content related to organismal interactions resulting in intersexual and intrasexual selection in greater detail. As such, I asked if the depiction of sex roles in Animal Behavior textbooks reflected the classic, androcentric paradigm shown to dominate the Evolution textbooks, and whether response to scholarly critique was evidenced by change over time in the images presented. I asked:

1. How are sex roles depicted in Animal Behavior textbooks?
2. Is there an androcentric bias rooted in human gender stereotypes evident in images of organisms in Animal Behavior textbooks?
3. Do these textbook characteristics change over time?

Considering the trends in scientific literature and substantial history of interdisciplinary scholarly critique, I expected current Animal Behavior textbooks to [1] depict an expanded, updated view of animal sex roles that illustrates variation and complexity as opposed to limiting depiction of sex roles to the classic paradigm, and [2] given the historical focus of research on males, androcentrism will be evident in animal images but, [3] this will decrease over time and there will be an increase in female representation and images depicting expanded sex roles over the 11 edition time series.

SELECTION OF TEXTBOOKS AND IMAGES

To determine which textbooks to include in the study, I conducted an internet search of large (>20k students) public universities in the United States for information about Animal Behavior and Behavioral Ecology courses and found 75 classes at 59 academic institutions for which information on required textbooks was made publicly available. Most of these were upper-level biology classes (n = 57), and 85% of the courses adopted one of four current-edition textbooks published between 2012-2017. I examined the images in these four textbooks as well as those from a series of 11 editions of the most widely adopted textbook (required by 41% of the classes) to characterize the presentation of sex roles in Animal Behavior textbooks and to evaluate change over time.

I analyzed images from textbook chapters covering topics specifically related to *reproductive behavior*, *mating systems*, and *parental care*, and searched the textbook indexes to locate additional relevant content outside of these chapters. I examined photographs and illustrations; multi-image figures were recorded individually if labeled and described as such (e.g., *Fig. 1a, Fig. 1b*, etc.) but were otherwise considered as a single image. Sexes depicted in the images were coded as male, female, both male and female, or unknown; the sex of some individuals was inferred based on descriptions provided in the text or figure legend, and images depicting organisms whose sex could not be determined were excluded from analyses.

CONTENT ANALYSIS

I developed a codebook informed by literature on sexual selection, feminist critiques of the theory, previous studies analyzing textbook images, and recommendations from Brugeilles & Cromer (2009). To validate the coding process, two investigators coded a set of images separately before comparing codes; after reviewing discrepancies, interrater reliability of subjective coding was calculated using Cohen's Kappa, and percent agreement among investigators was perfect.

To determine the extent to which Animal Behavior textbooks incorporated expanded views of animal sex roles, I classified images as depicting either *classic* or *expanded* sex roles. Classic sex roles were defined as those which reflected the classic Darwin-Bateman paradigm (e.g., competitive males and choosy females); expanded sex roles were defined as those which complicated the classic paradigm (e.g., mutual mate choice, biparental care, female agency) or depicted sex roles as flexible or dynamic in response to external stimuli (e.g., resource availability).

To characterize the sex roles and concepts represented in the textbook images, I examined the broad topics addressed by the textbook chapters and produced seven topical categories, three of which aligned with my original search topics (i.e., reproductive behavior, mating systems, and parental care), and four of which emerged during overview of the chapters: sex differences, competition for mates, mate choice, and sexual conflict. Each topic encompassed multiple subtopics (e.g., the topic *competition for mates* included the subtopics *affiliative interactions* and *agonistic interactions*) and each subtopic encompassed multiple possible concepts for which an organism might be depicted (e.g., the subcategory *agonistic interactions* included concepts such as *combat* and *armaments*). Finally, I recorded the species and sex(es) portrayed, as well as the topics, subtopics and separate concepts depicted by animals shown in the images; these data were then used to help inform my classification of the sex roles represented by the images as either *classic* or *expanded*, to examine relationships between the taxa and concepts depicted, and to compare topics of focus across textbooks and time.

I used several metrics to examine the depiction of the sexes within the textbooks using a feminist lens. To characterize the representation of females and males, I compared counts of female-only images, male-only images, and images depicting both sexes, as well as the concepts depicted for each sex or combination thereof. I recorded the location of images on the page (i.e., top, middle, or bottom) and within a chapter (i.e., page number in chapter), and noted whether they were placed within the text, on the page margin, or situated within a call-out box. I drew from Dimopoulos et al. (2003) to describe the vertical angle from which images subjects were depicted, as low angle shots make subjects appear more powerful while high angle shots make objects appear less significant (Kress & Van Leeuwen, 1996).

To compare the language used to describe females and males in the textbooks, I compared the sex(es) of individuals visually depicted in the images with the sex(es) *explicitly* mentioned or *implicitly* referenced in the accompanying legends. I considered a sex to be explicitly mentioned if the legend used the words *male* or *female* when describing an image but considered reference to a sex implicit if the legend referenced it indirectly. For example, if a legend read *"The male grabs the female,"* both the male and female are explicitly mentioned; however, if instead it read *"The male grabs his mate,"* the male is explicitly mentioned but the female is only implicitly referenced vis-à-vis possession by the male (i.e., *his* mate).

Finally, I categorized legend descriptors of females and males as either *active*, *reactive*, *passive,* or *none* (Karlsson Green & Madjidian, 2011). Descriptors for a sex were coded as *active* if an action was described as initiated by an individual but were coded as *reactive* if an action was described as occurring in response to the presence or action of another individual. Alternatively, descriptors were coded as *passive* if an individual was referenced in the legend but was either [1] not described as engaged in an activity (e.g., a description of an ornament), or [2] was included as a non-reactive component of an interaction. For example, if a legend read *"Females release pheromones which attract several eager males,"* the female descriptor would be coded as *active* — as females are described as initiating an interaction — and the male descriptor would be coded as *reactive* — as the female action elicits a direct behavioral response from males. Alternatively, if a legend read *"Male elephant seals aggressively defend their harems,"* the male descriptor would be coded as *active*, and the female descriptor coded as *passive*, as females are referenced implicitly vis-à-vis non-reactive membership of the male's harem.

RESULTS

EMPHASIS ON CLASSIC SEX ROLES

Images in the current Animal Behavior textbooks presented primarily classic views of animal sex roles (Table 1). Among the 403 images examined, 321 (80%) depicted classic sex roles, mainly competitive males and female choice, but also maternal care, sexual dimorphism, and sexual conflict (Table 2). The 82 images that presented expanded views of animal sex roles also depicted a variety of subtopics — including biparental care, flexible mating behavior, monogamy, polyandry, extrapair copulations, male choice, female agency in reproductive decisions, sex changes, and female ornamentation — yet more than 1/3 of the images highlighting expanded sex roles focused on paternal care (Figure 1). Images that depicted classic sex roles appeared earlier in the chapters ($\mu = 15.4$, $SD = 10.31$) than those that depicted expanded sex roles ($\mu = 15.0$, $SD = 8.93$) and were also more evenly distributed throughout the chapters. There was no significant difference between the sexes in the proportions of images depicting expanded versus classic sex roles (Fisher's exact test, $p = 0.08$), however, mammals were depicted more often in classic than expanded sex roles, whereas fish were depicted more often in expanded than classic sex roles (X^2 = 14.36, df = 5, p = 0.013; Figure 2).

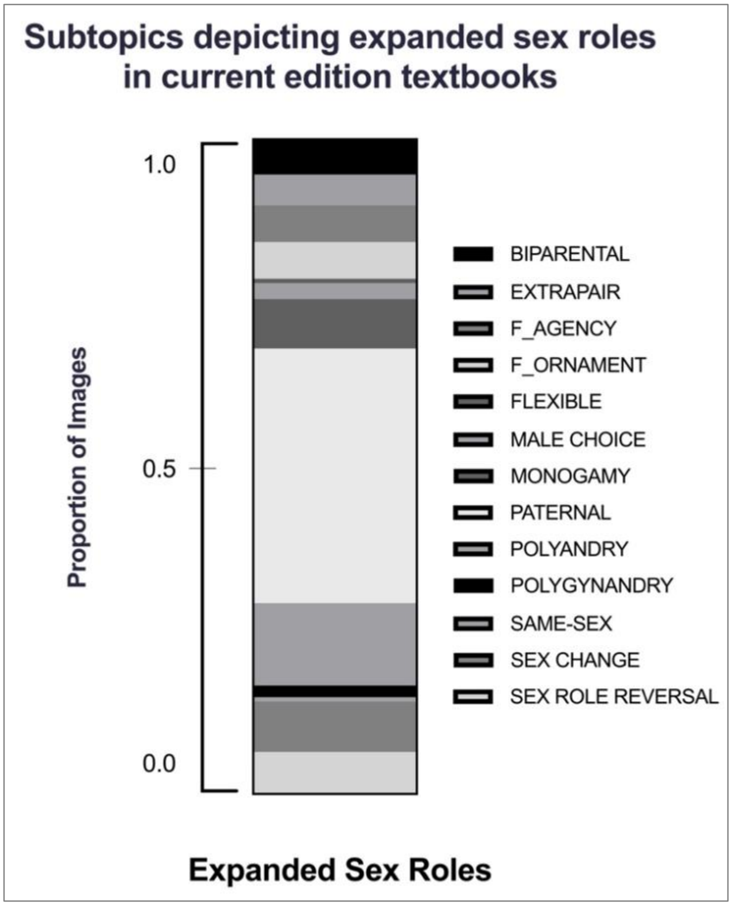


Figure 1. **Proportion of subtopics for current Animal Behavior textbook images depicting expanded sex roles.** Most images highlighted examples of male parental care.

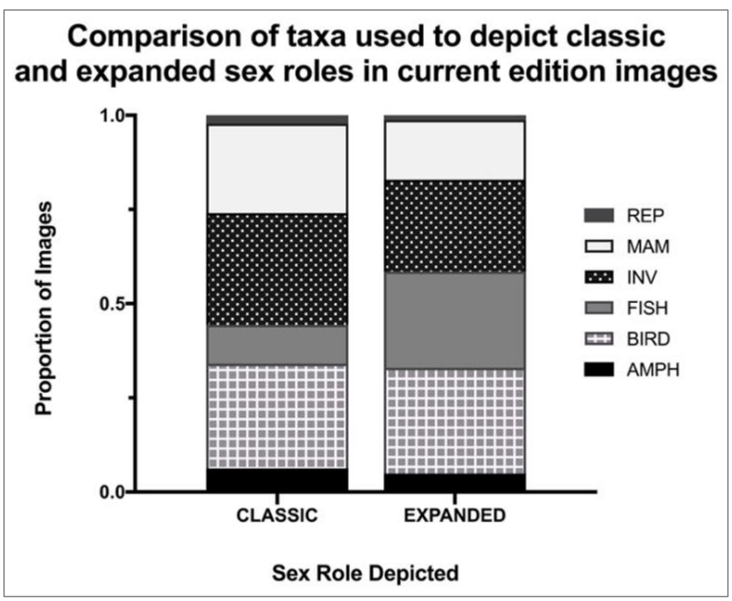


Figure 2. **Proportion of classic and expanded sex roles depicted by taxa.** Mammals were depicted significantly more often in classic sex roles, whereas fish were depicted significantly more often in expanded sex roles (X^2 = 14.36, df = 5, p = 0.013).

Table 1

Counts and percentages of classic versus expanded views and sexes depicted in current edition textbook images.

			SS View				Sex					
Publisher	Year	Images	Classic		Expanded		*M*		*F*		*M + F*	
		(n)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)
Alcock	2013	163	125	76.7	38	23.3	76	46.6	24	14.7	63	38.7
Davies	2012	87	74	85.1	13	14.9	51	58.6	6	6.9	30	34.5
Dugatkin	2014	71	54	76.1	17	23.9	33	46.5	15	21.1	23	32.4
Nordell	2017	82	68	82.9	14	17.1	43	52.4	17	20.7	22	26.8

Note. M: male pictured, F: female pictured, B: both sexes pictured

Counts and percentages of classic versus expanded views and sexes depicted in time series.

			SS View				Sex					
Edition	Year	Images	Classic		Expanded		*M*		*F*		*B*	
		(n)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)
1st	1975	41	35	85.4	6	14.6	13	31.7	12	29.3	16	39.0
2nd	1979	67	60	89.6	7	10.4	23	34.3	11	16.4	33	49.3
3rd	1984	91	80	87.9	11	12.1	39	42.9	17	18.7	35	38.5
4th	1989	89	73	82.0	16	18.0	41	46.1	13	14.6	35	39.3
5th	1993	114	90	79.0	24	21.0	62	54.4	19	16.7	33	28.9
6th	1998	137	112	81.8	25	18.2	71	51.8	25	18.2	41	29.9
7th	2001	147	114	77.6	33	22.4	75	51.0	23	15.6	49	33.3
8th	2005	151	118	78.2	33	21.8	83	55.0	21	13.9	47	31.1
9th	2009	170	131	77.1	39	22.9	91	53.5	29	17.1	50	29.4
10th	2013	163	125	76.7	38	23.3	76	46.6	24	14.7	63	38.7
11th	2019	162	125	77.2	37	22.8	84	51.9	23	14.2	55	34.0

Note. M: male pictured, F: female pictured, B: both sexes pictured

Table 2
Counts (n) and percentages (%) of subtopics depicted in current edition textbook images by author and sex(es) in image.

Subtopic	Alcock		Davies		Dugatkin		Nordell		B		F		M	
	(n)	**(%)**	(n)	**(%)**	(n)	**(%)**	(n)	**(%)**	(n)	**(%)**	(n)	**(%)**	(n)	**(%)**
Affiliative	22	**13.5**	18	**20.7**	15	**21.1**	18	**22.0**	35	**25.4**	6	**9.7**	32	**15.8**
Agonistic	23	**14.1**	22	**25.3**	16	**22.5**	6	**7.3**	14	**10.1**	1	**1.6**	52	**25.6**
Biparental	1	**0.6**	.	.	2	**2.8**	1	**1.2**	4	**2.9**	.	.	.	.
Conflict	19	**11.7**	2	**2.3**	.	.	.	.	14	**10.1**	3	**4.8**	4	**2.0**
Deception	1	**0.6**	0	.	.	.	.	.	.	.	.	.	1	**0.5**
Extrapair	2	**1.2**	0	.	2	**2.8**	1	**1.2**	1	**0.7**	1	**1.6**	3	**1.5**
Female Choice	18	**11.0**	9	**10.3**	8	**11.3**	15	**18.3**	13	**9.4**	3	**4.8**	34	**16.7**
Fitness	.	.	1	**1.1**	.	.	1	**1.2**	2	**1.4**	.	.	.	.
Flexible	1	**0.6**	.	.	.	.	.	.	.	.	1	**1.6**	.	.
Male Choice	2	**1.2**	.	.	.	.	1	**1.2**	1	**0.7**	2	**3.2**	.	.
Maternal	5	**3.1**	3	**3.4**	10	**14.1**	11	**13.4**	.	.	29	**46.8**	.	.
Mating	8	**4.9**	2	**2.3**	.	.	3	**3.7**	13	**9.4**	.	.	.	.
Monogamy	6	**3.7**	1	.	2	**2.8**	.	.	4	**2.9**	3	**4.8**	2	**1.0**
Multiple Systems	.	.	.	.	2	**2.8**	.	.	.	.	2	**3.2**	.	.
Mutual Choice	.	**0.0**	1	**1.1**	.	.	.	.	1	**0.7**	.	.	.	.
Paternal	16	**9.8**	4	**4.6**	4	**5.6**	7	**8.5**	2	**1.4**	.	.	29	**14.3**
Polyandry	11	**6.7**	.	.	1	**1.4**	2	**2.4**	3	**2.2**	5	**8.1**	6	**3.0**
Polygynandry	2	**1.2**	2	**2.3**	.	.	2	**2.4**	3	**2.2**	1	**1.6**	2	**1.0**
Polygyny	13	**8.0**	12	**13.8**	5	**7.0**	8	**9.8**	11	**8.0**	2	**3.2**	25	**12.3**
Sex Change	.	.	4	**4.6**	.	.	.	.	2	**1.4**	1	**1.6**	1	**0.5**
Sex Differences	12	**7.5**	3	**3.4**	4	**5.6**	6	**7.3**	14	**10.1**	1	**1.6**	10	**4.9**
Sex Role Reversal	1	**0.6**	3	**3.4**	.	.	.	.	1	**0.7**	1	**1.6**	2	**1.0**

In the time series, the proportion of images and variety of subtopics depicting expanded sex roles increased slightly over time (Table 2). In the first edition, two subtopics (i.e., paternal care and female agency) comprised 14.6% of the images examined (n = 6); these numbers increased to 11 expanded subtopics depicted by 22.8% of the images (n = 37) in the 11th edition (Figure 3a). The proportion of images depicting polyandrous and monogamous species increased in later editions, however nearly half of the images highlighting expanded sex roles in the most recent edition of the series remained focused on paternal care (n = 15). Among images depicting classic sex roles, much of the focus throughout the series remained on competitive males (Figure 3b). Depictions of maternal care declined over time, from 22.9% of classic images (n = 8) in the 1st edition to 3.2% of classic images (n = 8) in the 11th edition, as the proportions of images depicting female choice and sexual conflict increased. The distribution of classic versus expanded sex roles throughout the chapters mirrored the pattern seen in the current textbooks and, over time, the proportion of mammals and birds depicted for expanded sex roles decreased, while the proportion of fish and invertebrates depicted for expanded sex roles increased (Figure 4).

ANDROCENTRIC BIAS

SEX REPRESENTATION AND IMAGE PLACEMENT

There were significantly more male-only images than female-only images (exact binomial goodness-of-fit test of 1:1 M:F ratio; $p < 0.0001$) across the 403 images examined from the current textbooks — 34.2% of the images depicted both sexes, 15.4% depicted females, and 50.4% depicted males. Nearly two-thirds of the current-edition

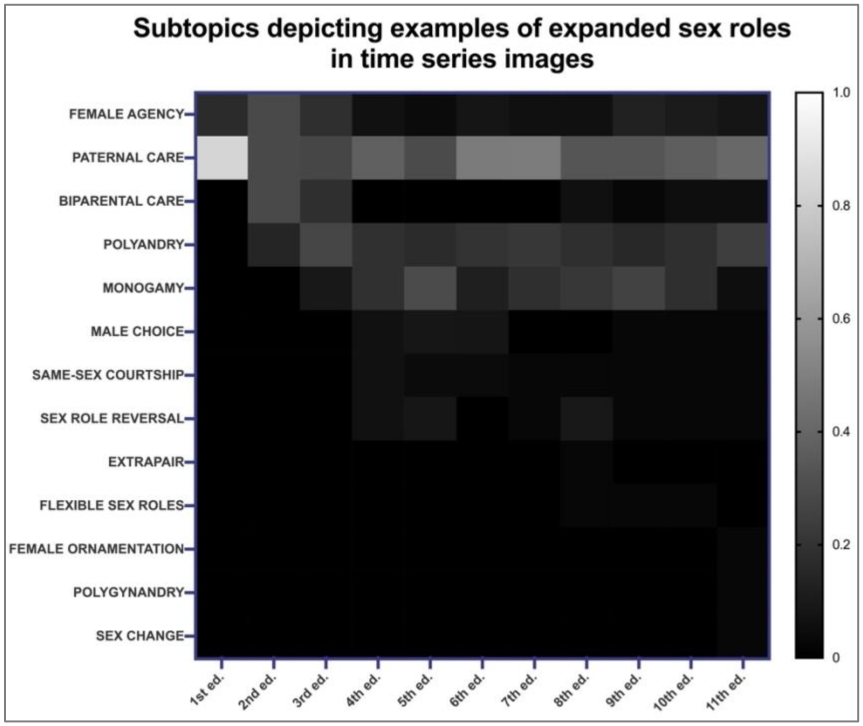


Figure 3a. **Proportions of expanded sex roles depicted over 11 edition series.** Most expanded images focused on paternal care, though the inclusion of images depicting polyandry and monogamy increased over time.

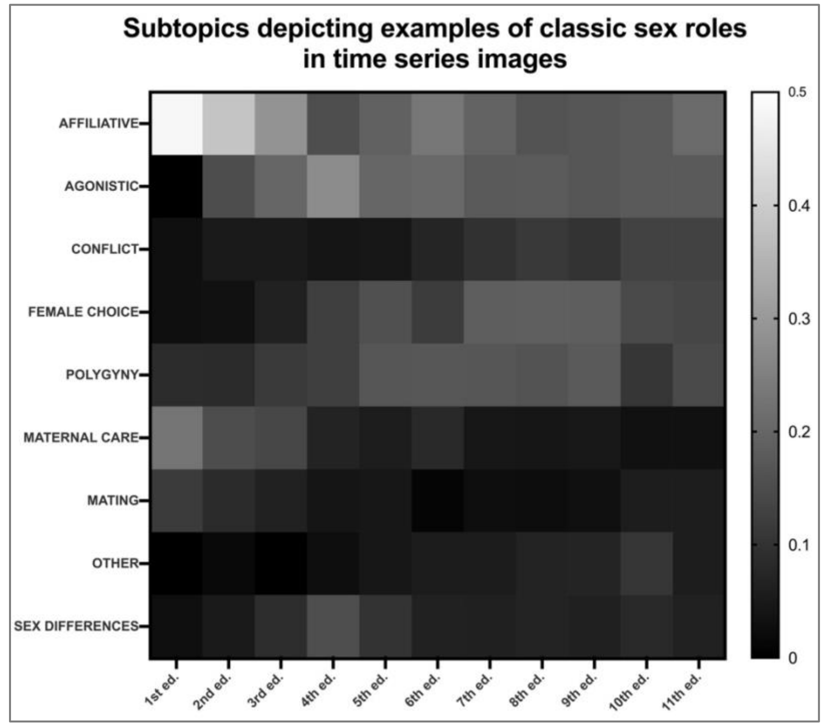


Figure 3b. **Proportions of classic sex roles depicted over 11 edition series.** Most classic images focused on males competing for access to mating opportunities, though the inclusion of images depicting sexual conflict increased over time.

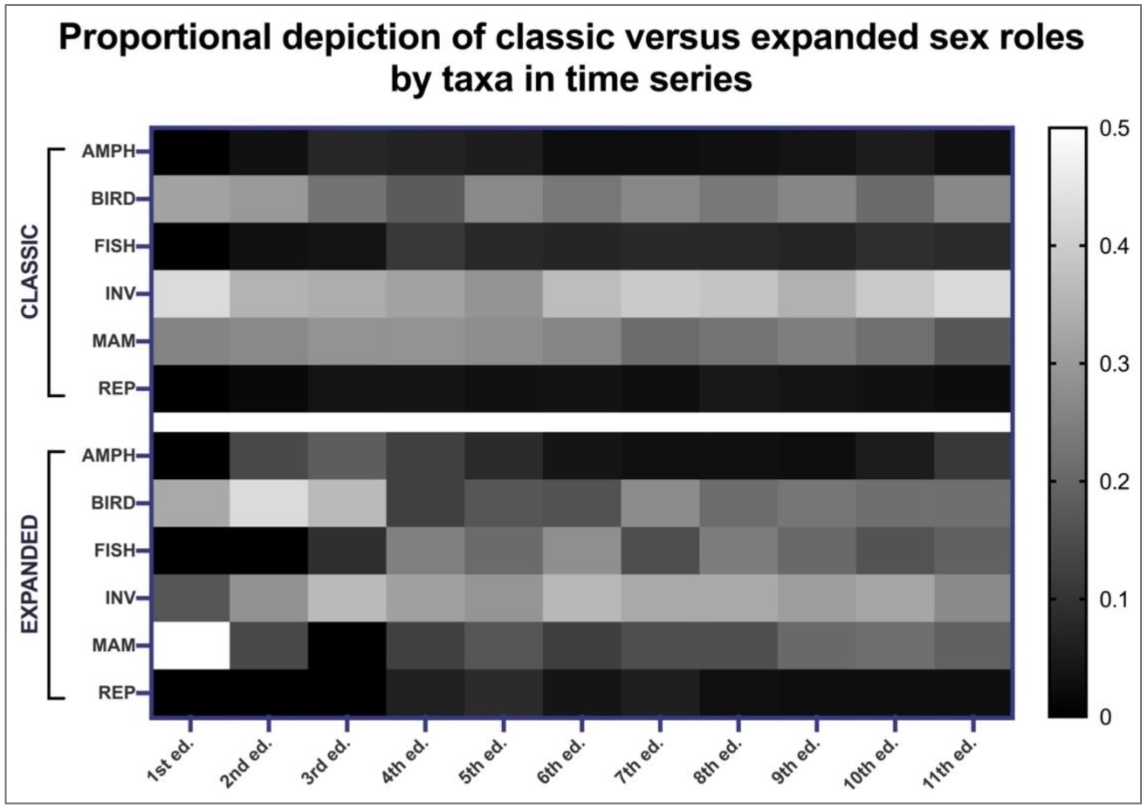


Figure 4. **Proportional depiction of taxa for classic and expanded sex roles in 11 edition series.** Over time, the proportions of classic images depicted by birds and mammals increased, while the proportions of expanded images depicting fish and invertebrates increased.

images (n = 246) were located within the text of the chapters; most of the call-out images were located on the page margin (Table 3), and males were no more likely to be situated in such visually prominent locations than were females (X^2 = 6.544, df = 4, p = 0.1620). The sexes did not differ in their locations on a page (X^2 = 4.494, df = 2, p = 0.1057); however, male-only images were more evenly distributed throughout the textbook chapters, whereas images depicting both sexes and females only were more often clustered near the start of the chapters. Additionally, females were significantly more likely to be framed from above — making them seem smaller and less significant — whereas males were typically framed from below or at moderate angles (X^2 = 15.60, df = 2, p = 0.0004) — making them seem larger and more powerful.

Opposite the trend expected, the proportion of female-only images decreased over time (Figure 5), from 29.3% in the 1st edition to 14.2% in the 11th edition (n = 23), while the proportion of male-only images increased from 31.7% in the 1st edition to 51.9% in the 11th h edition (n = 84). In general, the number of images highlighted by placement in visually prominent locations increased for both sexes from 1975 to present. Similar to the pattern observed in the current editions, throughout the time series male-only images and images depicting both sexes were more evenly distributed within the textbook chapters, whereas female-only images were more often clustered near the start of the chapters. Consistent throughout time, females were framed from above and rarely depicted from powerful angles (Figure 6a) while males were framed from below or eye level (Figure 6b).

Table 3

Counts and percentages of call-out images by author for current edition textbooks

Publisher	Year	Images (N)	Call-out Type: Box (n)	Box (%)	Entire Page (n)	Entire Page (%)	Margin (n)	Margin (%)	Total (n)	Total (%)
Alcock	2013	163	.	.	5	7.8	59	92.2	64	39.3
Davies	2012	87	1	2.1	4	8.5	42	89.4	47	54.0
Dugatkin	2014	71	1	2.6	4	10.3	34	87.2	39	54.9
Nordell	2017	82	9	50.0	.	.	9	50.0	18	22.0

Note. Percentage values for *Box*, *Entire Page*, and *Margin* call-out images were calculated based on total number of images situated in visually-prominent locations. The *Total* call-out percentage value was calculated based total number of images in a textbook.

Counts and percentages of call-out images by sex for current edition textbooks

Sex(es) Depicted	Images (N)	Call-out Type: Box (n)	Box (%)	Entire Page (n)	Entire Page (%)	Margin (n)	Margin (%)	Total (n)	Total (%)
Both	138	3	6.4	2	4.3	42	89.4	47	34.1
Female(s)	62	3	13.0	.	.	20	87.0	23	37.1
Male(s)	203	17	19.5	6	6.9	64	73.6	87	42.9

Note. Percentage values for *Box*, *Entire Page*, and *Margin* call-out images were calculated based on total number of images situated in visually-prominent locations. The *Total* call-out percentage value was calculated based total number of images for sex of interest in a textbook.

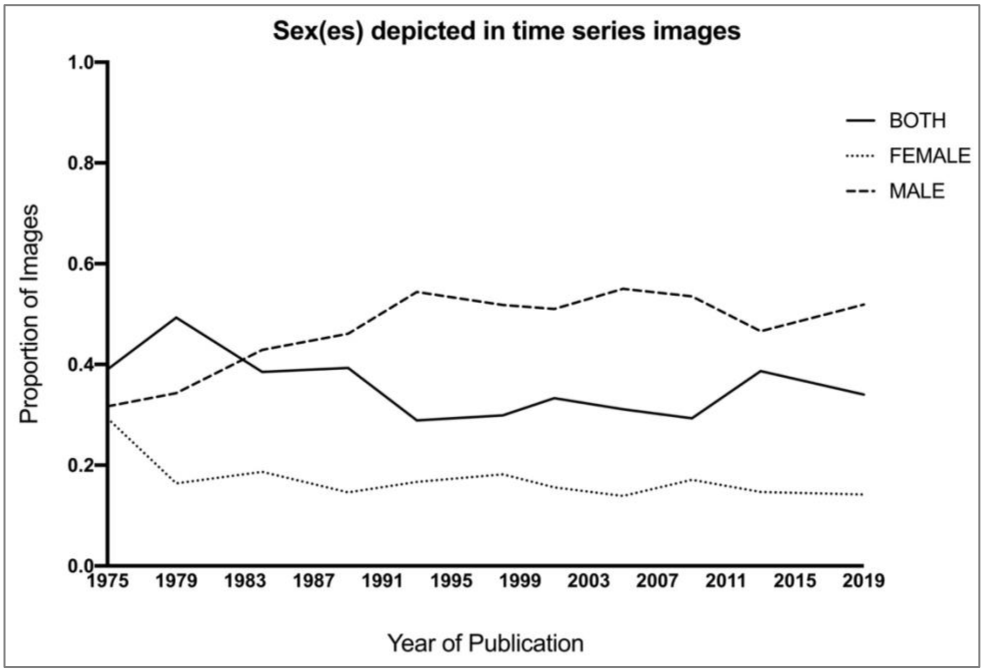


Figure 5. **Proportion of single-sex and both-sex images in 11 edition series of Animal Behavior textbooks**. Over time, the proportion of female-only images decreased while the proportion of male-only images increased.

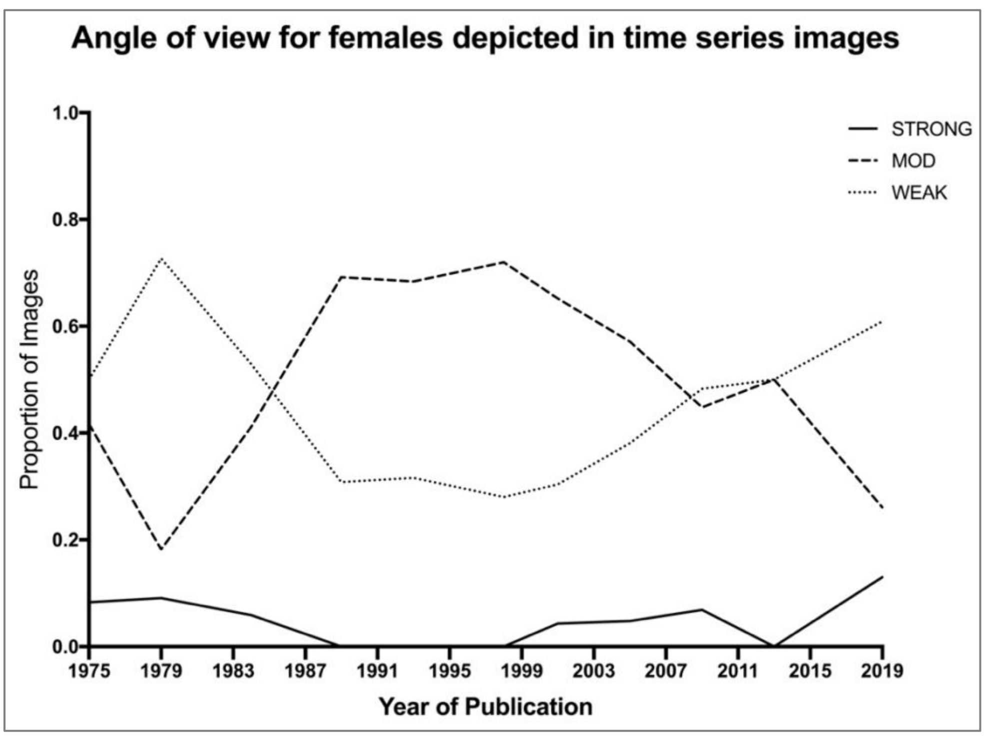


Figure 6a. **Proportions of females depicted from strong, moderate, and weak angles in 11 edition series of Animal behavior textbooks.** Females were rarely depicted from powerful angles.

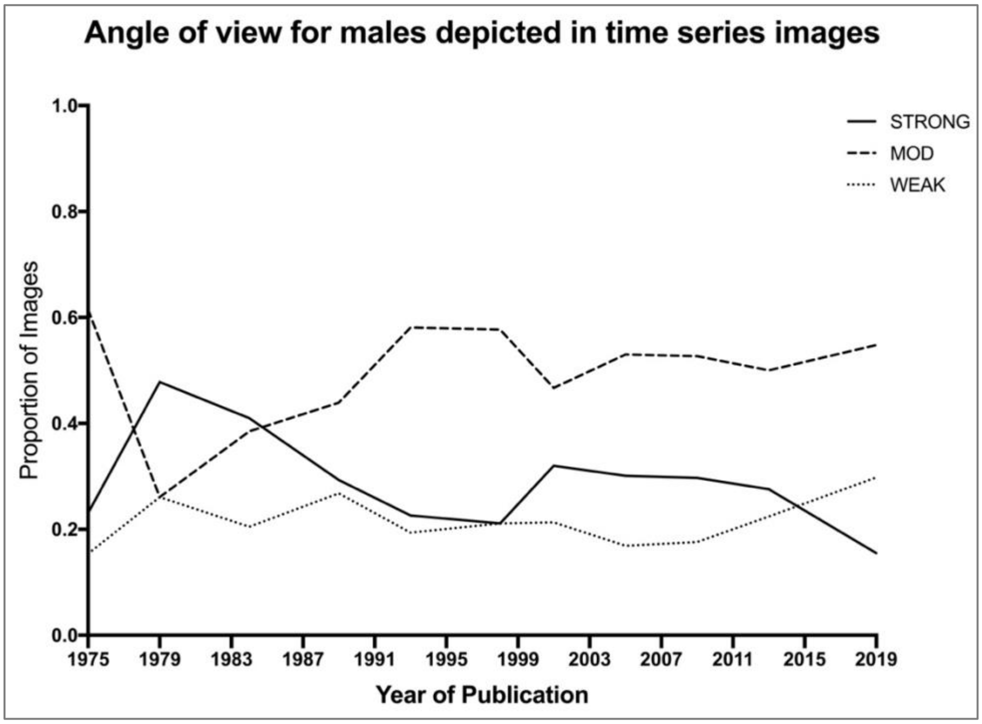


Figure 6b. **Proportions of males depicted from strong, moderate, and weak angles in 11 edition series of Animal behavior textbooks.** Males were largely depicted from powerful or moderate angles.

Subtopics

Among single-sex images in the current editions, females were used to exemplify 16 distinct subtopics while males were used to exemplify 14 subtopics (Table 2); however, there were more images per subtopic for males than females. For half of the subtopics (n = 7) illustrated by images of females, there was only one image per subtopic whereas for males, nearly all of the subtopics (n = 12) were illustrated with multiple images. For example, among the 25 images depicting the subtopic of sexual dimorphism, only one presented females-only, whereas 10 presented males-only (the remaining images contrasted both sexes). When females were pictured without males (n = 62), they were used to illustrate maternal care in 46.8% of the images (n = 29). Most of the remaining female-only images highlighted examples of choosy females, and only 9.7%

depicted expanded sex roles in which females competed for access to mating opportunities (n = 6). When males were pictured without females (n = 203), they were most commonly shown competing for access to mating opportunities (53.7% of the time; n = 109), or to illustrate paternal care (13.9% of the time; n = 29).

Among the single-sex images examined in the time series, the number of subtopics for which females and males were depicted were relatively similar and increased over time (Table 4). In the first edition, when males and females were pictured together, it was most often to depict concepts or activities associated with classic sex roles (e.g., polygyny), though images depicting both sexes engaged in sexual conflict (e.g., forced copulation) began to feature more prominently after the 5th edition. When females were pictured without males, it was most often to highlight examples of maternal care — though images depicting polyandrous females began to feature more prominently in later editions — and when males were pictured without females, it was often to highlight examples of competition for mates, female choice, or to highlight examples of paternal care.

Table 4
Number (n) and percentage (%) of subtopics depicted by sexes over time series.

Edition	Subtopics	Both		Female		Male	
	n	n	(%)	n	(%)	n	(%)
1st	8	7	(87.5)	3	(37.5)	5	(62.5)
2nd	11	10	(90.9)	4	(36.4)	6	(54.5)
3rd	12	10	(83.3)	6	(50.0)	9	(75.0)
4th	14	10	(71.4)	8	(57.1)	8	(57.1)
5th	17	11	(64.7)	11	(64.7)	10	(58.8)
6th	18	12	(66.7)	11	(61.1)	8	(44.4)
7th	20	15	(75.0)	11	(55.0)	8	(40.0)
8th	19	15	(78.9)	10	(52.6)	10	(52.6)
9th	20	15	(75.0)	12	(60.0)	11	(55.0)
10th	18	12	(66.7)	11	(61.1)	11	(61.1)
11th	16	11	(68.8)	10	(62.5)	11	(68.8)

Note. Proportions calculated based on total number of subtopics in edition.

IMAGE-LEGEND CONGRUENCE

In the current edition textbooks, incongruencies were detected between the sex(es) pictured and the sex(es) described in the legends of 39% (n = 157) of the images examined (Table 5). Incongruencies occurred among roughly half of all images depicting a single sex and the majority of these involved the explicit mention of both sexes in the legend but the visual depiction of only one sex. In general, females were more likely than males to be either implicitly recognized or completely omitted from legends associated with their images. Legends accompanying female-only images were more likely to implicitly reference the sex depicted than were legends of male-only images, ($X^2 = 22.82$, df = 4; p = 0.0001). Among images that pictured both sexes, 36% (n=9) omitted females from legends entirely and 40% (n=10) made only implicit references to females while explicitly mentioning males.

Table 5. **Proportion of legend incongruencies in current editions**

Author	Total	Congruent		Incongruent	
	n	n	(%)	n	(%)
Alcock	163	80	(49.1)	83	(50.9)
Davies	87	61	(70.1)	26	(29.9)
Dugatkin	71	49	(69.0)	22	(31.0)
Norton	82	56	(68.3)	26	(31.7)

Increase in proportion of legend incongruencies over time

Edition	Total	Congruent		Incongruent	
	n	n	(%)	n	(%)
1st	41	28	(68.3)	13	(31.7)
2nd	67	48	(71.6)	19	(28.4)
3rd	91	59	(64.8)	32	(35.2)
4th	89	45	(50.6)	44	(49.4)
5th	114	48	(42.1)	66	(57.9)
6th	137	66	(48.2)	71	(51.8)
7th	147	67	(45.6)	80	(54.4)
8th	151	71	(47.0)	80	(53.0)
9th	170	81	(47.6)	89	(52.4)
10th	163	80	(49.1)	83	(50.9)
11th	162	87	(53.7)	75	(46.3)

In contrast to my expectations, the percentage of image-legend incongruencies increased over time (Figure 7a), from 31.7% of images in the 1st edition (n = 13) to 46.3% of images in the 11th edition (n = 75).

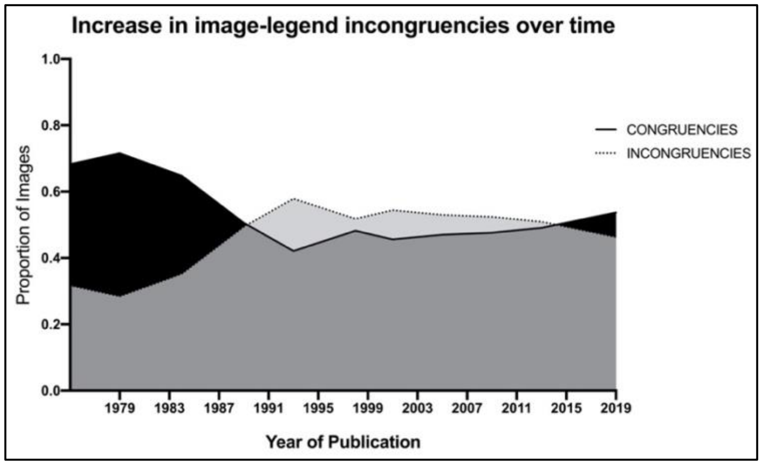


Figure 7a. **The proportion of image-legend incongruencies increased over time in the textbook series.**

Throughout the series, incongruencies occurred most often when an image depicted males without females (Figure 7b) but was accompanied by a legend which explicitly mentions both sexes (n = 311), or explicitly described males with an implicit reference to females (n = 107). However, the proportional increase in image-legend incongruencies can be attributed to images depicting females only; opposite the expected trend, for female-only images, the percentage of legends explicitly mentioning females comprised more than 75% of the images examined in the 1st edition and fell to 30.4% of images examined in the 11th edition (Figure 7c).

Figure 7b. **Most incongruencies occurred when both sexes were explicitly mentioned in legends accomanying male-only images.** B = both sexes; M = males; F = females; E = explicit; I = implicit.

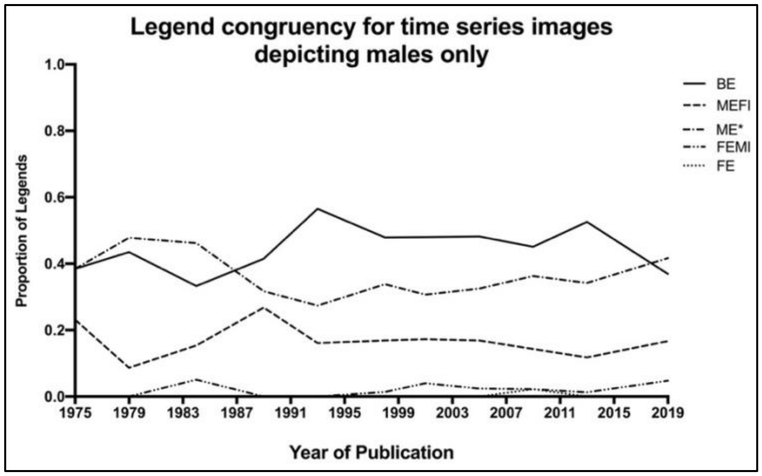
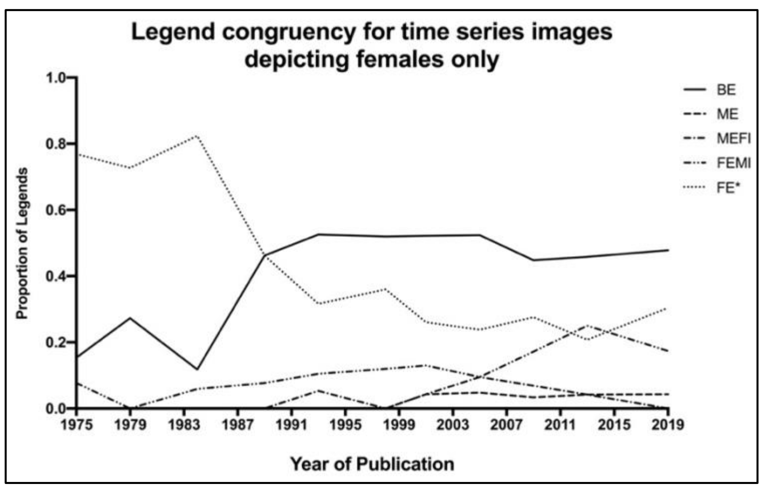


Figure 7c. **The increase in incongruence proportions over time is related to an increase in references to males in legends accompanying female-only images.** B = both sexes; M = males; F = females; E = explicit; I = implicit.



Additionally, several editions of the textbook series presented a photograph of a cichlid fish permitting offspring to feed off mucus excreted by its body. In earlier editions, this image was presented as depicting *maternal* care; however, later editions presented the same photograph in the context of *paternal* care, with no indication provided by the author as to why this change in depiction occurred. In a similar example, all editions of the textbook series presented a photograph showing one Hanuman langur attacking another. In earlier editions, this image was presented as depicting males competing for access to mates via agonistic interactions; however, later editions presented the same photograph in the context of infanticidal conflict between the sexes — again, with no indication as to why this change in depiction occurred.

LEGEND DESCRIPTORS

Analyses of the language used in the legends indicated significant differences in the sex-specific descriptors among images depicting both sexes and males only, but not among images depicting females only. Consistent with hypotheses of androcentric bias from a feminist perspective, among images depicting both sexes, descriptions of males were significantly more likely to use *active* language, whereas those of females used *passive* language (X^2 = 144.8, df = 3, p < 0.0001; Figure 8a).

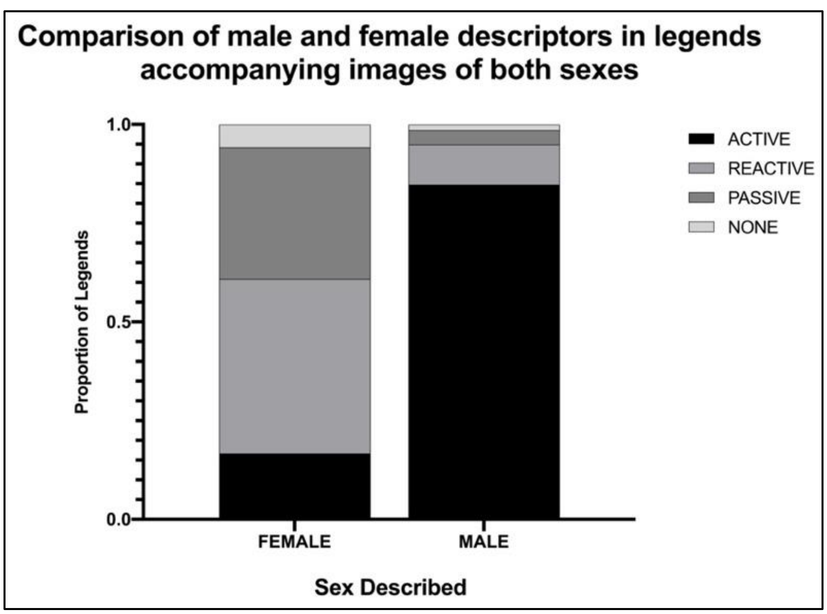


Figure 8a. **Comparison of male and female descriptors in legends accompanying images depicting both sexes.** Males were significantly more likely to be described as active, whereas females were described as passive or reactive (X^2 = 144.8, df = 3, p < 0.0001).

Among the images depicting males only, males were significantly more likely to be described as *active*, while females were more likely to be described as *reactive* (X^2 = 164.4, df = 2, $p < 0.0001$; Figure 8b). Alternatively, though females in female-only images were more likely to be described in the legend using *active* descriptors, there was no significant difference between the descriptors used for females versus those used for males in legends accompanying female-only images (X^2 = 5.541, df = 2; p = 0.0626, Figure 8c).

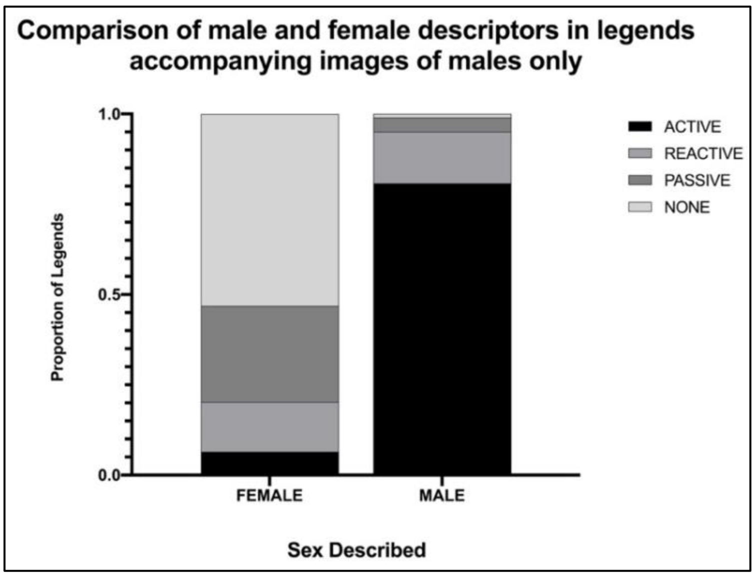


Figure 8b. **Comparison of male and female descriptors in legends accompanying images depicting males only.** Males were significantly more likely to be described as active, whereas females were described as reactive (X^2 = 164.4, df = 2, $p < 0.0001$).

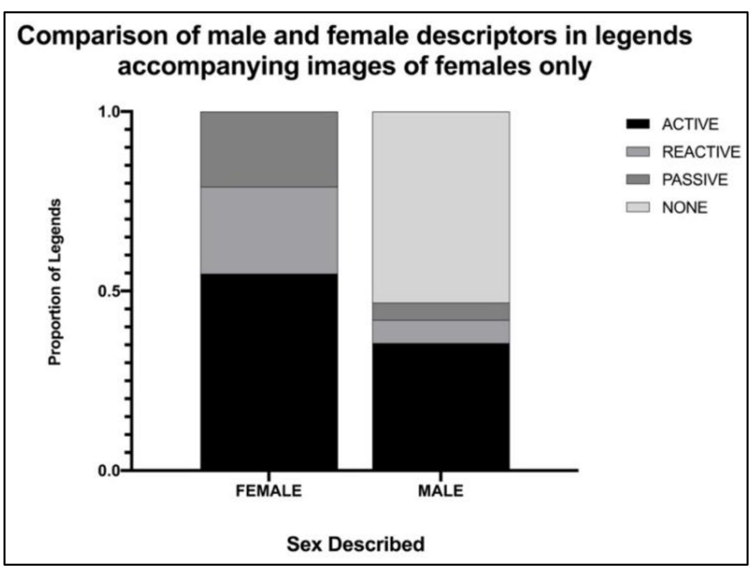
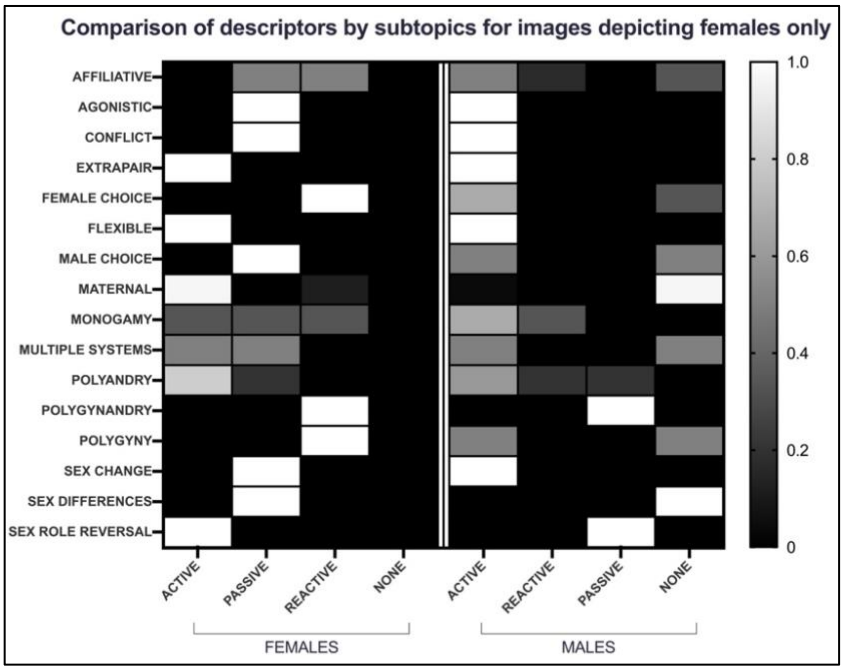


Figure 8c. **Comparison of male and female descriptors in legends accompanying images depicting females only.** Males and females were equally likely to be described as active despite not being visually represented (X^2 = 5.5, df = 2, $p <$ 0.06).

A comparison of the descriptors used for males and females by subtopic found that for images showing both sexes, most of the females described as *active* were depicted as engaged in mutual mate choice or extra-pair copulations (Figure 9a). In contrast, males were described as *active* most of the time with the exception of images depicting sex role reversed species.

Figure 9a. **Comparison of male and female descriptors by subtopic for legends accompanying images depicting both sexes.**



For images showing either males *or* females, I expected the sex depicted to be described as *active* most of the time with little to no mention of the sex not shown. And yet, for female-only images, females were often described as passive or reactive for subtopics in which they were active participants (e.g., polygynandry; Figure 9b), while *active* descriptors of males were often used for subtopics in which one would expect males to be depicted as *reactive* or *passive* participants (e.g., polyandry) — a pattern also observed in male-only images (Figure 9c).

Figure 9b. **Comparison of male and female descriptors by subtopic for legends accompanying images depicting females only.**

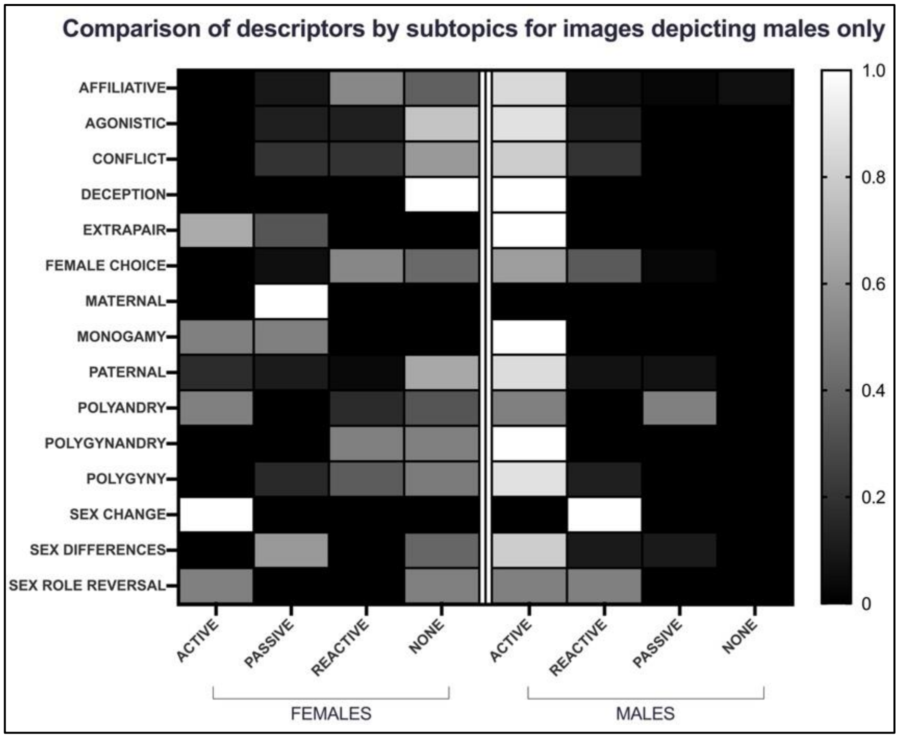
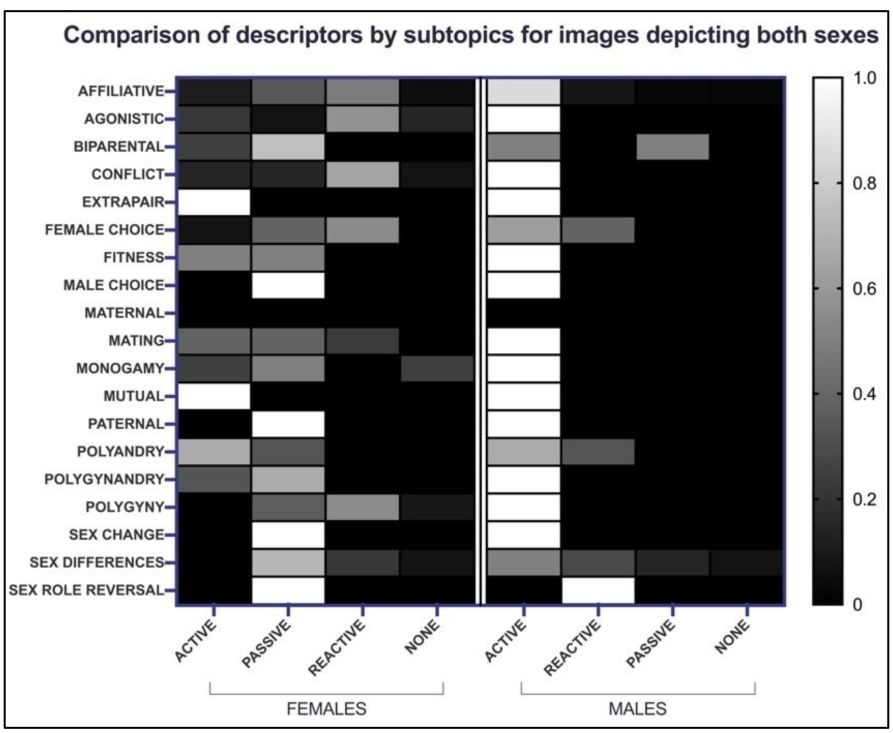


Figure 9c. **Comparison of male and female descriptors by subtopic for legends accompanying images depicting males only.**



Throughout the time series, the actions and behaviors of males were more likely to be described as *active*, while the actions and behaviors of females were more likely to be described as either *passive* or *reactive*. Over time, for images depicting both sexes, the proportion of *passive* descriptors for females decreased while the proportion of *reactive* descriptors increased (Figure 10a). No such change over time occurred for males, who were consistently described as *active* (Figure 10b).

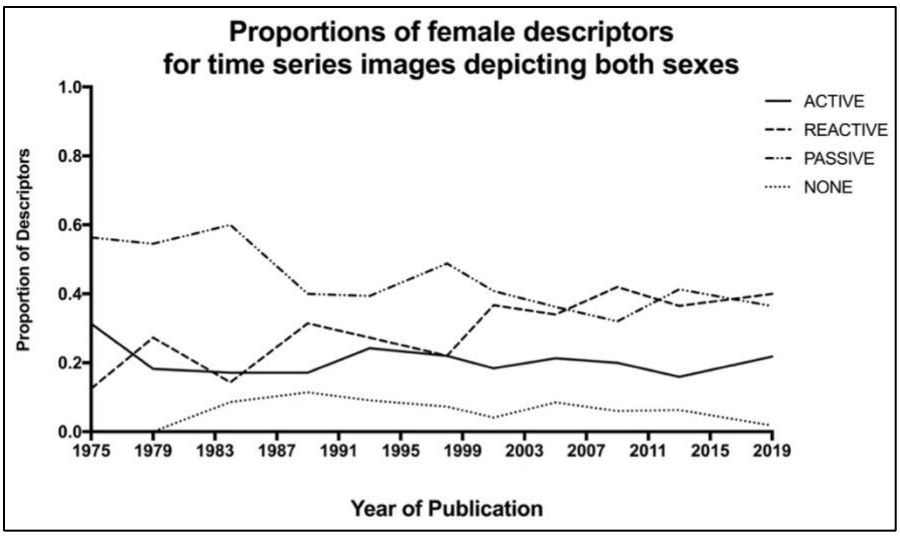


Figure 10a. **Proportion of legends describing females as reactive increased over time for images depicting both sexes.**

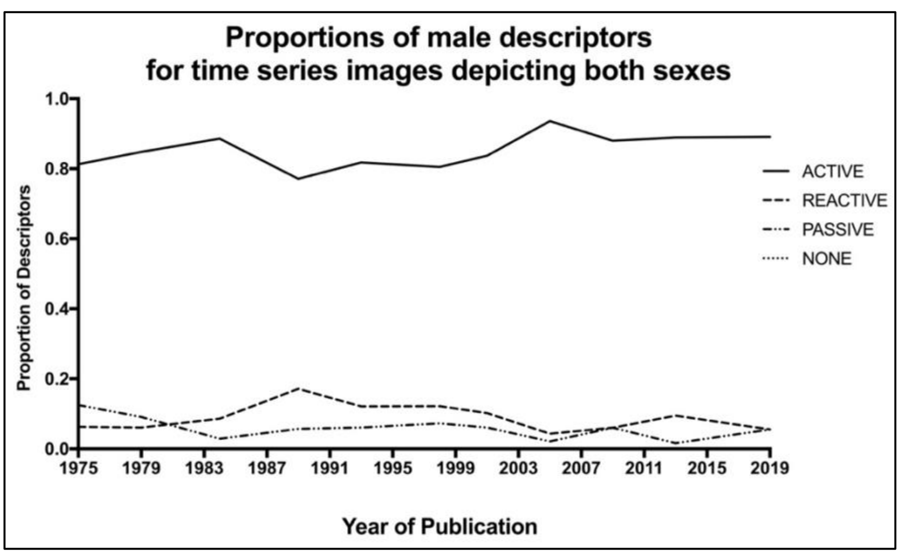


Figure 10b. **Males were consistently described as active throughout the time series.**

There was no significant difference among the textbook editions in the proportions of descriptors used to describe the actions and behaviors of females among images depicting females only (X^2 = 13.18, df = 20; p = 0.8695); throughout the series, females in female-only images were described using *active* descriptors roughly half of the time, and *reactive* and *passive* descriptors roughly 25% of the time (Figure 11a).

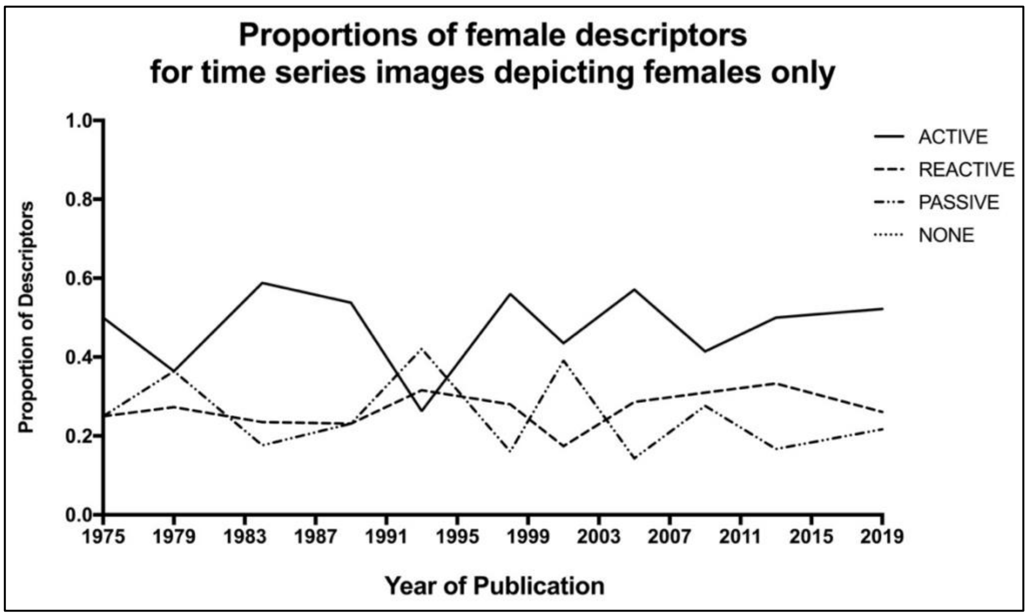


Figure 11a. **Proportion of female descriptors for legends accompanying time series images depicting females only.**

Descriptions of males in legends accompanying female-only images increased over time; earlier editions typically lacked mentions of males whereas in later editions, males were significantly more likely to be mentioned using *active* descriptors (X^2 = 46.54, df = 30; p = 0.0276; Figure 11b) despite occurring in legends accompanying images depicting females only.

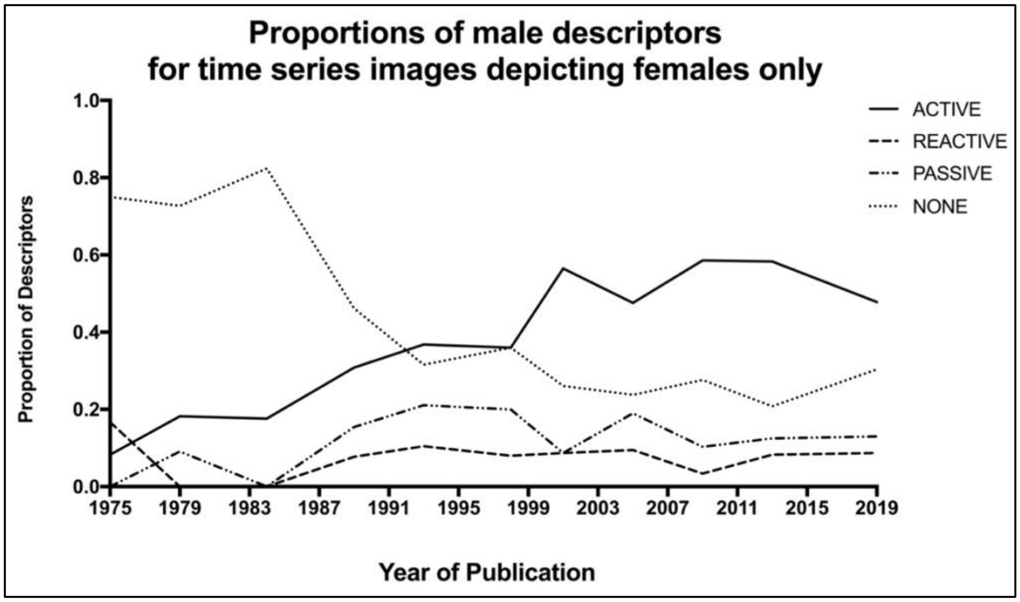


Figure 11b. **Proportion of male descriptors for legends accompanying time series images depicting females only.**

Among the images depicting males only, males were almost always described as *active*, although in later editions the proportion of *active* descriptors for males decreased slightly as the proportion of *reactive* descriptors increased (Figure 12a).

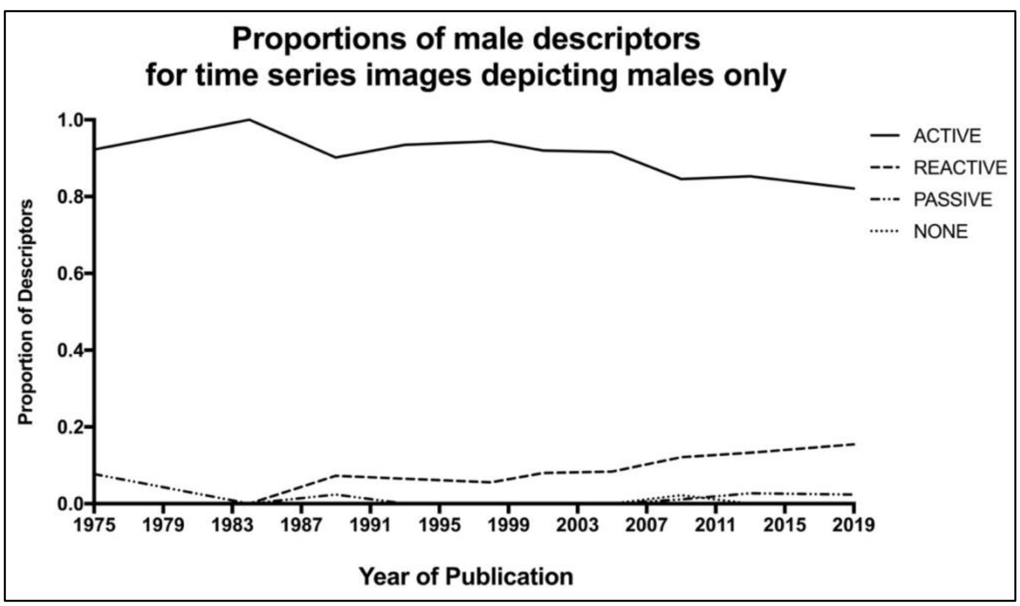


Figure 12a. **Proportion of male descriptors for legends accompanying time series images depicting males only.**

Descriptions of females in legends accompanying male-only images increased slightly over time from 38.5% of legends in the 1st edition to 54.8% of legends in the 11th edition; throughout the series, females were generally described in male-only images using *reactive* descriptors, although in later editions the proportion of *passive* and *active* descriptors increased slightly (12b).

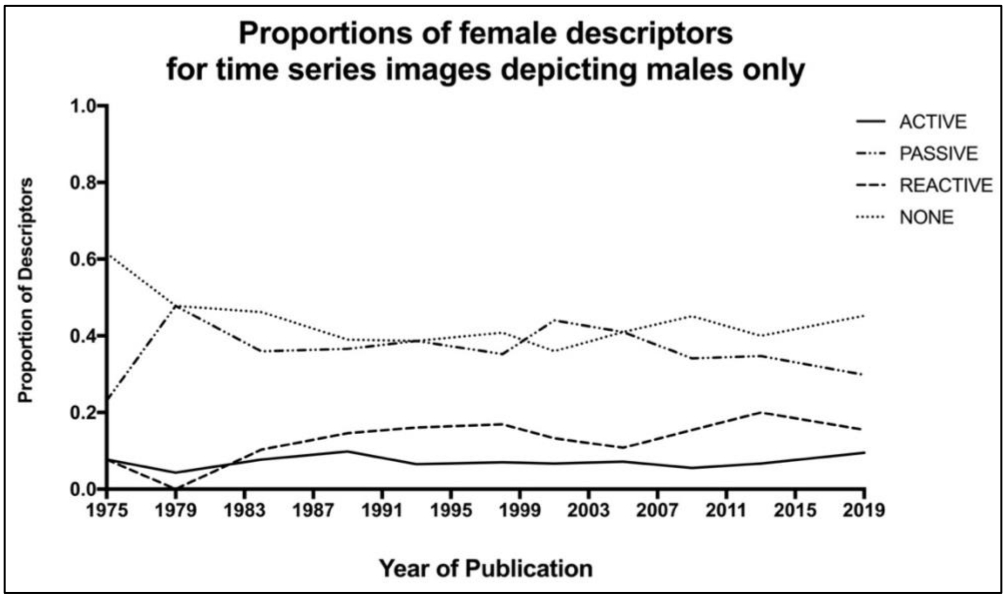


Figure 12a. **Proportion of male descriptors for legends accompanying time series images depicting males only.**

DISCUSSION

Images in Animal Behavior textbooks do not appear to reflect the expansion of sexual selection theory observed in the scientific literature over the last half century (Tang-Martinez, 2016), and the same sex/gender stereotypes and androcentric bias that appear in the textbooks of other academic disciplines are manifest among images of non-human animals in Animal Behavior textbooks. Problematically, the textbooks miss multiple opportunities to explicitly emphasize the iterative and social nature of science knowledge production and fail to highlight the importance of professional critique from diverse perspectives — key tenets of CCE (Longino, 2002). Rather, Animal Behavior textbooks perpetuate sex/gender inequality vis-à-vis the omission of females and communicate, *from a position of disciplinary authority*, the hidden message that the accomplishments and qualities of females are less important than those of their male counterparts (Porreca, 1984).

HOW ARE SEX ROLES DEPICTED IN ANIMAL BEHAVIOR TEXTBOOKS?

I expected that the images and concepts presented in current Animal Behavior textbooks would portray a more expanded view of animal sex roles, given the trends in scientific literature and substantial history of critique put forth by feminist science scholars. In contrast, the images primarily depicted an androcentric, classic view of sex roles that does not convey the complexity of sexual selection, particularly with respect to selection acting on females. Because textbooks are such influential enculturation devices, emphasizing classic sex roles not only portrays a narrow view of sexual selection, but also disregards legitimate criticisms and risks encouraging sex/gender stereotypes and biases (Fausto-sterling, 1997; Sutherland, 1985; Tang-Martínez, 2012).

Most of the images across the textbooks presented a narrow view that emphasized the multitude of ways in which males compete for access to mating opportunities, neglecting a valuable opportunity to inculcate an interest in and understanding of the incredible variation observed in reproductive behaviors. There was a disproportionate focus on paternal care as an example of expanded sex roles — considering several textbooks claimed that females are the sole providers of parental care for most animal species, and Evolution textbooks have been shown to emphasize other expanded concepts (i.e., polyandry and female agency; Fuselier et al., 2016; 2018). Additionally, the textbooks risk the implicit endorsement of negative human gender stereotypes by depicting mammals in classic sex roles significantly more often than in expanded sex roles, as the tendency to anthropomorphize non-human animals has been shown to increase with increasing phylogenetic relatedness to our own species (Harrison & Hall, 2010). In human societies, these roles are often intuitively linked to gender stereotypic behaviors that often result in the differential treatment of men and women on the basis of their perceived sex (Ah-King, 2013).

Do textbooks evidence androcentric bias rooted in gender stereotypes?

I expected that the number of male-only and female-only images would be similar, if not slightly male-biased, as sexual reproduction requires the active engagement and contribution of distinct gametes. And yet, androcentrism in Animal Behavior textbooks was manifest in the preponderance of male-only images. For example, there were five times as many male-only images depicting various iterations and fitness benefits of polygyny than there were for females and polyandry. This emphasis on a simplified dichotomy of competitive males and choosy females perpetuates the false notion that sex roles are binary and fixed and renders females — and behavioral variation — invisible. Certainly, differences between the sexes may be identified among any species if one looks long and hard enough. However, the background assumptions of researchers influence their questions and methodologies, and feminists have argued that these internal forces have driven ethologists to focus their investigations on behaviors that reflect determinist sex stereotypes (e.g., dominance in males and parental care in females) while neglecting the investigation of behaviors which may conflict with implicit sex/gender biases (Hrdy, 1984). Thus, current edition Animal Behavior textbooks emphasize the oversimplified stereotypes of male dominance and superiority manifested through human biases that color data collection and interpretation.

Also problematic is the frequency with which females are mentioned in legends accompanying male-only images, a phenomenon which suggests that although the authors acknowledge the importance of the contributions of females in reproductive interactions, females do not warrant equitable visual representation. This bias is also evident in legends accompanying female-only images, within which females are again depicted as passive or reactive while males are described as active. In fact, the androcentric and stereotypic language used by textbook authors often reflects the heavily-critiqued language of earlier seminal studies (Karlsson & Madjidian, 2011).

The overwhelming presentation of females depicted from weak angles communicates a hidden message of female powerlessness, as vertical positions have been found to embody human conceptions of power (Schubert, 2005). Additionally, the consistency with which passive and reactive descriptors are used to describe females is — as a long-criticized androcentric maneuver argued to limit scientific progress and reinforce cisgender stereotypes (Gowaty, 1997; Karlsson & Madjidian, 2011; Ah-King & Ahnesjö, 2013) — problematic for its communication and endorsement of implicit biases. If educational images function as a medium of communication whereby educators emphasize the most relevant disciplinary knowledge to their students and textbooks are representing females as less powerful, less important, and less active than males, then the internalization of these visual metaphors by science educators and their students risks perpetuating determinist perspectives that function to perpetuate unfavorable stereotypes (Keller, 2005) and the exodus of women from the scientific academe (Ah-King, 2018).

CONCLUSION

Despite a gradual increase in the occurrence of expanded sex roles over time, the patterns seen in the time series do not represent assimilation of change in the discipline. Although textbook production is an iterative, complex, and time-consuming process, empirical studies investigating expanded concepts began appearing in scientific journals nearly 50 years ago (e.g., Barlow et al., 1977; Weber & Weber, 1976; Wasser, 1983) and have steadily increased in number since. Thus, textbook authors have had decades to incorporate examples that depict a more complex and accurate picture of the scientific community's understanding of sexual selection theory to students. In fact, the noticeable increase in attention paid to sexual conflict beginning in the 1990's is demonstrative of rapid uptake of new scientific knowledge following an increase in related publications from just one decade prior (e.g., Thornhill & Thornhill, 1983; Arnqvist, 1989; Buskirk et al., 1984; Schuster & Sigmund, 1981).

The textbooks we require our students to engage with are powerful tools that make objective claims to knowledge from a position of disciplinary authority, yet these data reflect a failure by textbook authors to adequately respond to interdisciplinary critique and uptake new information that conflicts with an established paradigm. The tenets of CCE provide an approach for transparency and fluidity in the production of scientific knowledge, whereby the scientific academe may create thoughtful and equitable educational initiatives that are supportive and inclusive of all students, foster inclusivity, and encourage a lasting interest in scientific endeavors. Longino (2002) argues that knowledge is more objective when informed by diverse perspectives; however, if the perpetuation and internalization of sex/gender biases encourages the exodus of those who feel marginalized or stereotyped by the community, the production of objective scientific knowledge is quite seriously compromised. Alternatively, if textbook authors and educators explicitly highlight the nature of science (e.g., Allchin, 2014; Niaz & Maza, 2011) and inculcate within their curriculum the iterative and social nature of objective knowledge construction (Longino, 2002), then the exposure of tacit biases and subsequent edification of scholarship will follow.

CHAPTER THREE

USING PHOTO-ELICITATION TO EXAMINE UNDERGRADUATE STUDENT PERCEPTIONS OF NON-HUMAN ANIMAL SEX ROLES

INTRODUCTION

THE HIDDEN CURRICULUM

Images are increasingly presented to students in educational settings to aid in the depiction of complex topics; they capture attention, improve student learning, and are used to emphasize important disciplinary concepts (Carney & Levin, 2002; Myers, 1988). However, just as science scholars have scrutinized the purported objectivity of data collection and analysis within scientific research, sociologists engaged in image-based research have argued that even photographs do not provide unbiased documentation of the world (Prosser & Schwartz, 1998). Rather, images used in educational settings (e.g., those included in textbooks) reflect the social context and disciplinary conventions in which they were conceived and developed. Additionally, images are not passive vessels from which all students necessarily infer the same meaning. Schwartz describes the process of viewing an image as:

> *… a dynamic interaction between the photographer, the spectator, and the image; meaning is actively constructed, not passively received.* (1989, pp. 120).

In other words, the images used to aid in the instruction of complex topics function as a medium of explicit and implicit communication between educators and students. Given the context in which they are presented, it is unsurprising that students may interpret educational images as visual depictions of claims to knowledge. Students often lack the "visual literacy" that would enable them to recognize implicit social messages or biases that may be communicated when images are used to present, for example, complex scientific concepts (Bowen & Roth, 2002; Pauwels, 2008), presenting educators with several challenges.

As the disciplinary authorities charged with the presentation of knowledge, educators at all levels of instruction are often required to teach courses or cover content which falls outside one's specific "knowledge niche." Thus, instructors often rely heavily on academic textbooks and supplemental material to guide their curriculum and, in effect, communicate to students [explicitly] what *is* and [implicitly] what *is not* relevant disciplinary knowledge (Sadker & Zittleman, 2007). This dependence on textbooks as pedagogical tools has, in a number of ways, perpetuated the hidden curriculum of gender bias in education. Studies have shown that women are underrepresented in textbook images across multiple disciplines (e.g., Hogben & Waterman, 1997; Parker et al., 2017; Damschen et al., 2005), men are depicted as the anatomical norm (Lawrence & Bendixen, 1992), and women and men are most often pictured in gender stereotypical roles (Gullicks et al., 2005; Hogben & Waterman, 1997; Metoyer & Rust, 2011; Moore & Clarke, 1995; Peterson & Kroner, 1992; Parker et al., 2017). Importantly, the potential for harm lies not just in the perpetuation of inaccurate facts or inequitable representation. The educational images presented to students in textbooks and the classroom communicate the epistemic convictions of disciplinary experts. Thus, educators risk the implicit reinforcement of harmful biases — and the endorsement of strict sex/gender stereotypes from a position of disciplinary authority — vis-à-vis the utilization of textbooks as pedagogical tools.

To address the disenfranchisement of women in society and scientific endeavors, consideration of the perpetuation of sex/gender stereotypes and biases in biology curricula is both timely and important. For example, previous studies examining the effects of gender stereotypic images found that the internalization of these biases [1] affects women's academic performance (Davies & Spencer, 2005; Good et al., 2010), [2] influences how students assess their own performance and that of their peers (Steele, 1997), and [3] affects the assessment of women scientists throughout the trajectory of their careers (Davies & Spencer, 2005; Moss-Racusin et al., 2012, 2015). Additionally, Good et al. (2010) demonstrated that sex-role stereotypic images of men and women reinforce implicit gender biases and affect the performance and retention of women in science. In their study, women who were presented with lessons in which they viewed "counter-stereotypic" images were found to have significantly higher comprehension of the scientific concepts measured than women who viewed sex-stereotypic images, and this pattern was reversed for men (Good et al., 2010). Perhaps more importantly, the researchers found that the science performance of women and men was *equalized* when the students were presented with a lesson in which disciplinary role models (i.e., female and male scientists) were depicted equitably and for equally important activities.

However, most of the images in biology textbooks depict nonhuman organisms, and, to my knowledge, no published data are available about how students perceive images of nonhuman animals depicted in sex-role stereotypic illustrations. Recent studies have shown that animals in biology textbooks are visually depicted in ways that reinforce human gender stereotypes (Fuselier et al., 2018; Spaulding, in review). Thus, it is imperative to examine student perceptions of these images, as the propensity of young adults to anthropomorphize non-human animal images (e.g., Harrison & Hall, 2010; Morris et al., 2000) suggests these images may be equally effective at communicating sex/gender stereotypes and implicit biases as are images of humans in textbooks from other disciplines.

ANTHROPOMORPHIC SEX ROLES

Within evolutionary biology, the tenets of sexual selection have been employed in the effort to better understand animal sex roles (i.e., collective patterns of behavior between individuals engaged in competition for mating opportunities, exerting mate choice, providing parental care, and other behaviors centered around reproductive ecology; Ah-King & Ahnesjö, 2013). However, given that our interpretations of animal behaviors are colored by our own experiences and limitations as humans, it is unsurprising that human explanations of animal behaviors often ascribe human societal norms and values to the motivations and interactions of non-human species. In the broadest sense, anthropomorphism can be defined as *the attribution of human characteristics to that which is not human* (Epley et al., 2007). Although criticized as a flawed methodology which produces biased, androcentric assumptions about the conscious mental content of non-human animals (Watson, 1913; Libell, 2014), the practice of anthropomorphizing is inadvertently reinforced by disciplinary authorities within the scientific community. For example, biology textbooks have been shown to humanize female animals through narratives of nurturing, maternal care while males are framed in a dominant and possessive light (Ewald, 2016). Such anthropomorphic depictions of non-human species risk communicating the implicit but authoritative endorsement of biological determinism and gender essentialist stereotypes. Thus, they have been criticized for promoting a heteronormative narrative which (1) fails to reflect the flexibility of behaviors exhibited in the reproductive interactions of male and female animals (Tang-Martinez, 2016), and (2) endorses a *competitive males and choosy females* dichotomy that serves to reinforce the dominant, gender-stereotypic narrative shaped by societal and cultural norms (Ah-King & Ahnesjö, 2013). In concert with the historical exclusion of engagement by women in scientific inquiry, this approach has both fueled the perception of gendered differences in personality traits and encouraged the acceptance of biological determinism by driving what questions are asked and how science is done (Ah-King & Ahnesjö, 2013).

Although no longer considered writ large within the scientific community, biological determinism has historically provided a scientific basis from which moral arguments have been made asserting the inferiority of individuals who are not white, male, and heterosexual. Notably, this controversial perspective implies that human behavior is an innate quality determined by biological attributes rather than social or cultural forces (or a combination of the two) and has been used by those in power to reinforce oppressive social values and conditions (Ahnesjö et al., 2020). Importantly, it conflates biological sex and gender identity, fashioning the *sex-gender-sexuality system* in which we find ourselves, described by Gayle Rubin (1984) as “the set of arrangements by which a society transforms biological sexuality into products of human activity.” However, *sex* and *gender* are neither synonymous nor easily disentangled and defined. For example, humans possessing XY chromosomes can (but don’t always) produce sperm and those possessing XX chromosomes can (but don’t always) produce ova and gestate offspring, and many physiological and behavioral traits considered to be distinct criteria of maleness or femaleness occur simultaneously within individuals and may change over time (Gowaty, 2018). Recent work by Fausto-Sterling (2019) emphasizes the multidimensionality and inextricable link between human sex and gender — gendered structures have been shown to affect biological structures and vice versa, and neither are fixed traits which can be measured by a single, validated approach — and Gowaty (2018) describes gender as a *process of becoming* that occurs over the course of a lifetime and is shaped by biological, psychological, and sociocultural forces.

And yet, cultural attitudes about appropriate gendered behaviors manifest at a young age and increase over a person’s lifetime (Reis & Wright, 1982). Men are generally less egalitarian than women (Dunn, 1979; King, 1979; Marke & Gottfries, 1979), and implicit biases cultivated through the reinforcement of negative gender stereotypes have relegated women to the status of vulnerable, passive caregivers while concomitantly elevating men to the status of protective, dominant providers (Larsen & Long, 1988). Combined with the historical exclusion of engagement by women in scientific inquiry, this has both fueled the perception of gendered differences in personality traits and encouraged the acceptance of biological determinism by driving what questions are asked and how science is done (Ah-King & Ahnesjö, 2013).

PURPOSE OF STUDY

The larger goals of this study were to [1] examine the degree to which undergraduate students apply anthropomorphic language and human gender stereotypes to images of nonhuman animals typical of those presented in sexual selection chapters of Biology textbooks, and [2] to determine if this is related to their identity as a biologist, sense of belonging within the university science community, and/or expression of implicit bias. Thus, I developed a photo-elicitation interview [PEI] to investigate how undergraduate men and women perceive nonhuman animal reproductive behaviors when presented with contextualized, decontextualized, and mis-contextualized images. I asked:

RQ 1: How do undergraduate men and women describe nonhuman animal reproductive behaviors when presented with contextualized, decontextualized, and mis-contextualized images typical of those presented in sexual selection chapters of Biology textbooks?

RQ 2: What patterns emerge among the language used by students in relation to the taxa, behaviors, and context depicted?

RQ 3: What patterns emerge in the relationship between the language used by students and their sense of belonging, science identity and implicit biases?

Given the ubiquity of anthropomorphic and sex-stereotypic terminology documented in textbooks and the scientific literature to describe animal sex roles, I expected that undergraduate students in both the STEM and non-STEM groups would employ similarly problematic language to describe the reproductive behaviors of nonhuman animals. Additionally, I expected that the assumptions and interpretations made by students would differ among the taxa and behaviors depicted, as students are more likely to anthropomorphize images of closely related taxa (e.g., primates; Harrison & Hall, 2010) and may be more likely to use anthropomorphic terminology when describing behaviors typical of humans (e.g., the reinforcement of parent-offspring social bonds). Finally, I expected to find differences among participant groups in term of biology identity, sense of belonging, and gender/science automatic associations, and anticipated that the use of anthropomorphisms and sex-stereotypic language may occur more often among individuals who automatically associate men with science and women with liberal arts but would not differ based on a student's science identity or sense of belonging within the scientific academe.

METHODS

STUDY POPULATION

This project took place at the University of Louisville and received IRB approval (RB 19.0121). Participant demographics reflected those of the larger university population; 60% identified as women, and 55% as white. Responses from individuals meeting exclusionary criteria were removed prior to analyses (i.e., students who failed to complete the interview or survey questions) leaving data from 287 students for investigation — 121 of whom were recruited from two sections of an introductory-level non-majors Biology course (hereafter the *non-STEM* group) and 166 of whom were recruited from one of eleven different upper-level Biology courses (hereafter the *STEM* group).

Participants in the non-STEM group were largely in their first or second year of college and were recruited from two sections of an introductory biology course that satisfies a general education requirement and has no prerequisite course requirements. These students represented a wide range of major areas of study, including nursing (n = 18; n = 15%), arts (n = 12; 10%), and finance (n = 11; 9%). Students in the STEM group most often identified a STEM-related field as their major area of study, were largely in their third or fourth year of college, and were recruited from a variety of 300, 400, and 500-level biology courses offered to science majors who have successfully completed several lower-level biology prerequisites.

On average, STEM students had successfully completed more than five college biology classes prior to taking part in my study, whereas all non-STEM students were, at the time of data collection, enrolled in their first biology class. Study participants selected their gender from a list of choices (*male*, *female*, *nonbinary*, and *other*), self-reported political ideology on a scale from 1-5 (where 1 = *extremely liberal*, and 5 = *extremely conservative*), self-reported religiosity on a scale from 1-5 (where 1 = *not at all religious*, and 5 = *extremely religious*), and answered an open-response question about race/ethnicity. The compositions of the STEM and non-STEM groups did not differ significantly by gender (Fisher's exact test, $p = 0.085$) or race ($X^2[3,276] = 5.58$, $p = 0.134$).

STUDENT PERCEPTIONS OF NON-HUMAN ANIMAL IMAGES

I developed a photo-elicitation interview [PEI] to examine student perceptions of non-human animals typical of those they would encounter in a biology textbook chapter covering reproductive behaviors. PEI is an interview technique in which images are used

—in addition to or instead of text — to elicit responses from participants. I predicted that a content analysis of student descriptions of non-human animals would reveal implicit anthropomorphic and gendered perspectives held by participants and elucidate the extent to which these are impacted by what the students *assume* or *think* they are viewing. During the spring and fall semesters of 2019, students accessed the PEI online using a university-associated survey platform. All participants were presented with the same nine photographs: three picturing mammals, three picturing birds, and three picturing fish. The photographs used in the PEI were selected to present a visual representation of one of three sex role-related behaviors for each taxon, including: Parental interactions (e.g., mouth brooding), Intrasexual interactions (e.g., agonistic combat), and Intersexual interactions (e.g., affiliative courtship).

Students were informed that investigators were interested in how they perceived images of non-human animals typical of those encountered in biology textbooks and prompted to describe the behavior of the focal animal(s) by providing details about the sex(es), behavior(s), and motivation(s) of the organisms in 2-3 sentences. Participants assigned to receive the *contextualized* treatment [CONTEXT] were presented with the images overlayed by text that identified the sex(es) of the focal animal character(s). Students assigned to receive the *mis-contextualized* treatment [MIS-CON] were presented with the images overlayed by text that misidentified the sex(es) of the focal animal character(s). Finally, students assigned to receive the *decontextualized* treatment [DE-CON] were presented with the images without any text identifying the sex(es) of the focal animal character(s). I expected that students would be more likely to use gendered and anthropomorphic language to describe images for which the sex of the animal was provided (i.e., CONTEXT and DE-CON treatments).

STUDENT MEMBERSHIP WITHIN THE UNIVERSITY BIOLOGY COMMUNITY

After completing the PEI, students were directed to complete three activities to provide insight into their self-perceptions of membership within the scientific academic community: [1] the biology-specific portion of the Science Identity survey to examine the extent to which students identify as *biologists* (Hazari et al., 2013); [2] an adapted version of the Psychological Sense of School Membership scale to examine the extent to which students feel like a part of the university biology community (Goodenow, 1993); and [3] an implicit bias test to examine the automatic gender/science associations held by students (Greenwald et al., 1998).

The biology portion of the Science Identity survey [BIO-ID] uses a 5-point scale (where 1 = *never/no, not at all* and 5 = *always/yes, very much*) with 9 questions developed to evaluate the extent to which students identify as a "biology type of person" (i.e., a *biologist*; Hazari et al., 2013). BIO-ID response scores near 1 indicate little to no self-identification as a biology type of person, while response scores near 5 indicate a strong self-identification as a biology type of person. I anticipated that mean BIO-ID scores would be higher among STEM students and, possibly, may differ between men and women. Relatedly, I expected that students with high BIO-ID scores would describe the behaviors they viewed with more conceptual accuracy than students with low BIO-ID scores but would not differ significantly among students who used anthropomorphisms and/or human gender stereotypes in their descriptions and those who did not.

I slightly altered the wording for the Psychological Sense of School Membership scale [PSSM] to reflect the specific university setting and department for this study and used a Likert scale (where 1 = *never* and 5 = *always*) with 18 questions designed to examine students' sense of belonging in the school social environment (Goodenow, 1993). For the PSSM, mean response scores near 1 were considered to reflect lower levels of psychological membership within the university biology community, while mean response scores near 5 were considered to reflect higher levels of psychological membership within the university biology community. I expected mean PSSM scores to be significantly higher among STEM students but predicted that, similar to BIO-ID scores, they would not differ significantly among students who used anthropomorphisms and/or human gender stereotypes in their descriptions and those who did not.

To measure the strength of automatic associations for participants between concepts (i.e., male vs. female) and attributes (i.e., sciences vs. liberal arts) of interest, students accessed the gender/science implicit association task [IAT] through Harvard's *Project Implicit* website (projectimplicit.net). Participants completed a series of automatic discrimination tasks in which they were directed to sort randomized combinations of words relating to concepts (e.g., father, sister) and attributes (e.g., philosophy, chemistry) into categories (Table 1). The IAT program characterized participant gender/science implicit associations using response latency times to measure differential associations between "male and female" concepts and "science and liberal arts" attributes; I was provided with qualitative IAT results that categorized students as depicting either strong, moderate, slight, or no automatic associations between female and male words and words related to the sciences and liberal arts. Student implicit bias data were de-identified and stored on a secure device for inclusion in data analysis. IAT categories were enumerated to establish a seven-point scale with which to compare levels of automatic association, and participants were assigned numerical IAT scores accordingly (where 1-3 = strong/mod/slight automatic women/science association, 4 = no automatic gender/science association, and 5-7 = slight/mod/strong men/science association).

RESULTS

CONTENT ANALYSIS

Images used in the PEI were categorized a priori as depicting *Parental, Intrasexual*, or *Intersexual* interactions. First-cycle codes for characterizing student image descriptions were inspired by findings in the textbook analysis (Spaulding, *in review*) and developed using an Eclectic approach that combined Descriptive and In Vivo coding methods (Saldaña, 2015). Iterative rounds of code-mapping and theming the qualitative data refined the data corpus into five main subcategories: [1] Image Concepts, [2] Anthropomorphisms, [3] Sex/Gender Stereotypes, [4] Sex References, and [5] Sex Descriptors; reliability of coding was established over multiple rounds of coding and discussion among researchers to achieve >90% interrater agreement.

IMAGE CONCEPTS

Eighteen distinct conceptual themes emerged among student descriptions for animals engaged in different categories of behavior (Table 2) and many overlapped among the student descriptions provided for Parental images (12 themes), Intrasexual images (17 themes), and Intersexual images (18 themes).

Table 1. **Schematic of the gender/science implicit association test [IAT]**

Sequence	1	2	3	4	5
Task Description	Initial target-concept discrimination	Associated attribute discrimination	Initial combined tasks	Reversed target-concept discrimination	Reversed combined tasks
Task Instructions	FEMALE ▶ ◀ MALE	SCIENCE ▶ ◀ LIBARTS	FEMALE ▶ SCIENCE ▶ ◀ MALE ◀ LIBARTS	◀ FEMALE MALE ▶	◀ FEMALE SCIENCE ▶ MALE ▶ ◀ LIBARTS
Example Stimuli	◀ Uncle ◀ Man Daughter ▶ Wife ▶ ◀ Nephew Sister ▶	Math ▶ ◀ English Geology ▶ Biology ▶ ◀ Music ◀ History	◀ Art Grandma ▶ Chemistry ▶ ◀ Brother ◀ Humanities Girl ▶	Dad ▶ ◀ Woman ◀ Aunt Husband ▶ ◀ Niece Grandson ▶	◀ Mother Astronomy ▶ ◀ Literature Boy ▶ Engineering ▶ ◀ Daughter

Note. Participants are introduced to target concepts and attribute dimensions in steps 1 and 2, and discriminations are randomly assigned to right (orange) or left (purple) responses. Concepts and attributes are combined in step 3 for assessment. Concept response assignments are reversed and practiced in step 4 and recombined with attributes in step 5 for comparison with participant response data from step

When describing the Parental images, students often emphasized themes of *protection* (e.g., "keeping babies safe" and "protecting from predators") and *parental care* (e.g., "taking care of young" and "watching over offspring"). Alternatively, when students described the Intrasexual images, they often emphasized themes of *dominance* (e.g., "fighting for leadership" and "trying to intimidate") and *sociality* (e.g., "playing around" and "they seem *friendly*"). Finally, when describing the Intersexual images, students often emphasized themes of *affiliative attraction* (e.g., "trying to impress" and "wants to win her over") and *sexual dimorphism* (e.g., "males have brighter colors" and "the small one is probably female"). Themes are defined in Table 3.

Table 2. **Themes which appeared in student descriptions for Parental, Intrasexual, and Intersexual images.**

	Image Category		
Theme	**Parental**	**Intrasexual**	**Intersexual**
Affiliative		x	x
Agonistic		x	x
Biparental	x	x	x
Care	x	x	x
Choose		x	x
Compete		x	x
Conflict	x	x	x
Construct	x		x
Dimorphism	x	x	x
Display		x	x
Dominance	x	x	x
Ecology	x	x	x
Guard		x	x
Portrait	x	x	x
Protect	x	x	x
Reproduce	x	x	x
Social	x	x	x
Teach	x	x	x

Note. Appearance of theme in image category indicated by "x"

Multiple anthropomorphic themes emerged among student descriptions of non-human animals (Table 4). Responses were coded as anthropomorphic [ANTHRO] if a student used terminology typically reserved for human family groups, emotions, social structures, conflicts, and behaviors to explain their perceptions of the non-human animal depicted. For example, when describing organisms depicted in parental care roles, students sometimes emphasized themes of human *family groups* (e.g., “the mother looks after her children”). Alternatively, when describing organisms depicted in affiliative interactions, students sometimes attributed human *emotions* to the focus animals (e.g., “the other female is jealous”).

Themes of human sex/gender stereotypes also emerged during the content analysis of student responses (Table 4). Responses were coded as stereotypic [STEREO] if a student ascribed gendered stereotypes to non-human animal behaviors. For example, when describing an animal depicted in the role of parental care, students often described the animals as *nurturing* and *loving* if they believed they were viewing an image of a female. Stereotypic responses were also seen in student responses about parental care. For example, students sometimes described males pictured in the role of parental care as engaged in *biparental care* when no female was depicted — that is, they assumed care was also provided by females (e.g., “the male is giving the mom a break from the babies so she can look for food”).

Table 3. **Descriptions of the 18 image concept themes that emerged from content analysis of student descriptions of PEI images**

Theme	Description	Example student response
Affiliative	Animal described as engaged in intersexual courtship	"*This appears to be a male and female in a mating ritual.*"
Agonistic	Animal described as engaged in intrasexual competition	"*These two males are competing for the chance to mate.*"
Biparental	Animal described as at least one of two different-sex individuals that provide parental care to the same offspring	*"This male is protecting his chicks while the mother is looking for food."*
Care	Animal described as caring for or watching over offspring	*"The male is cuddling his child in his arms."*
Choose	Animal described as chooser in reproductive interaction	*"The male has a feature which both the females find attractive."*
Compete	Animal described as engaged in competition for resources, territory	*"Two female mammals seem to be competing for something, maybe food."*
Conflict	Animal described as interfering with another organism's fitness	*"He is eating the eggs so the female will mate again."*
Construct	Animal described as constructing nest/home	*"The male bird is collecting objects to make a nest."*
Dimorphism	Appearance of sex described vis-à-vis comparison to other sex	*"The male is darker in color to attract the female's attention."*

Display	Animal described as engaged in courtship display (ornament, gift)	*"The male bird drops shiny objects to persuade the female to mate."*
Dominance	Animal described as establishing social dominance; hierarchy	*"These male fish are fighting to establish dominance."*
Ecology	Animal described in terms of niche filled	*"These animals are probably predators."*
Guard	Animal described as guarding or protecting mate	*"The male guards his mate from others to protect the chance that she will rear his offspring."*
Portrait	Animal described in generalities	*"A fish creature."*
Protect	Animal described as guarding or protecting offspring	*"The mother in the photo is protecting her young."*
Reproduce	Animal described as engaged in mating or offspring production	*"This female fish is spawning so a male can fertilize her eggs."*
Social	Animal described as engaged in unrelated social interaction	*"In this photo there are two males playing around."*
Teach	Animal described as teaching/ instructing another animal	*"She is instilling life skills that will be important for living in a group."*

Sex References & Descriptors

Drawing from the methodology developed for analyzing the language in legends accompanying textbook images (chapter one), the references and descriptors used by students to explain image concepts were also coded for further examination of the data. I considered a sex to be *explicitly* mentioned if a student response included sexed/gendered nouns (e.g., male, mother) in their description of the focal animals, but considered a sex to be *implicitly* mentioned if a student response instead used sexed/gendered or possessive pronouns (e.g., she, her) to describe a focal animal. Finally, sex descriptors were coded as *active* if an action or interaction was described as initiated by an individual but were coded as *reactive* if a behavior was described as occurring in response to the presence or action of another individual. Alternatively, descriptors were coded as *passive* if an individual was referenced in the legend but was either [1] not described as engaged in an activity (e.g., a description of an ornament), or [2] was included as a non-reactive component of an interaction.

Identity Descriptive Statistics

Summary data from the BIO-ID, PSSM, and IAT were examined for patterns among participants. A two-way ANOVA with BIO-ID score as the dependent variable and participant gender and group as the independent variables revealed a small but significant interaction effect of gender and group for BIO-ID scores (Figure 1; Table 6). The difference in mean BIO-ID scores between STEM and non-STEM men was much greater than the difference between mean BIO-ID scores of STEM and non-STEM women, possibly reflecting responses of the high proportion of women nursing students in the non-STEM group.

Table 4. **Anthropomorphic and stereotypic themes produced by content analysis of student descriptions of photographs of nonhuman animals**

Category	Theme	Description	Example student response
Anthropomorphisms			
	Family	Animals described using terms like "mother" or "children"	*"The father is looking out for his kids."*
	Emotions	Emotions like "jealous" or "happy" ascribed to animal	*"He chose the first female and the other is jealous."*
	Genders	Animal described using words like "man" or "woman"	*"The other female just swooped in to steal her man."*
Sex/Gender Stereotypes	Male providers	Females depicted as depending on males for support	*"The male is probably out foraging while the female stays at the nest."*
	Aggressive males	Males depicted as domineering, aggressive	*"These are most likely males due to their aggressive nature."*
	Female caregivers	Females depicted as nurturing, loving	*"This is a female bird that nests on its eggs and stays with its babies. It seems nurturing."*
	Coy females	Females shy, hiding	*"The female is hiding while the male searches for a mate."*

Table 5. **Sex reference and descriptor codes produced by content analysis of student descriptions of photographs of nonhuman animals**

Category Theme Description Example student response

Table 5. **Themes produced by content analysis of student descriptions of photographs of nonhuman animals**

Category	Theme	Description	Example student response
Reference	Assume	Focal animal sex is assumed	*"This is probably a female due to the babies around her."*
	Explicit	Focal animal sex is explicitly identified	*"These are two male birds competing over the female."*
	Implicit	Focal animal sex is implicitly identified	*"She is looking at her mate."*
Descriptor	Active	Animal described as actively engaged in interaction	*"Two females fighting for the male's attention."*
	Reactive	Animal is described as reacting to the action of another	*"The female chooses which male she prefers."*
	Passive	Animal referenced as non-reactive component	*"Eating habits of a fish."*

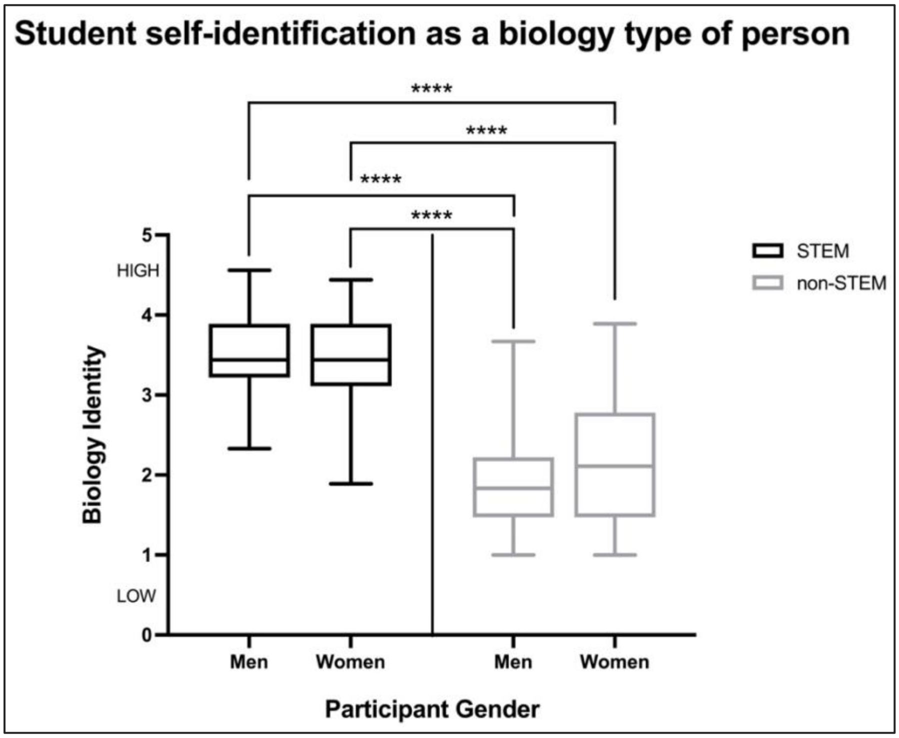


Figure 1. **Comparison of BIO-ID results by participant gender and group.** Students from the STEM group self-identify more strongly as biology types than non-STEM students do ($p < 0.0001$), but no significant difference in self-identification as a biology type of person was detected between men and women students overall.

Table 6. **Descriptive statistics and ANOVA summary table for BIO-ID scores**

Gender	Group	Mean	SD	N
Women	STEM	3.40	0.55	91
	non-STEM	2.13	0.80	80
Men	STEM	3.49	0.48	72
	non-STEM	1.83	0.55	40

Source of variation	df	SS	F	*P*
Group	1	136.0	1.73	**< 0.0001**
Gender	1	0.69	17.10	0.18
Group x Gender	1	2.49	15.95	**0.01**
Residual (error)	279	106.0		
Total	282	244.4		

As predicted, participants in the STEM group reported feeling a greater sense of psychological membership within the biology academe of the university than non-STEM students did; this further strengthens the categorization of the groups as STEM and non-STEM (Figure 2). Mean PSSM scores were significantly higher in the STEM group (F = 1.73, p = 0.0003; Table 3) but did not differ significantly between men (μ = 3.60, SD = 0.63) and women (μ = 3.71, SD = 0.70), and a two-way ANOVA with PSSM score as the dependent variable and participant gender and group as the independent variables revealed no significant interaction effects (F = 15.90, p = 0.12; Table 7).

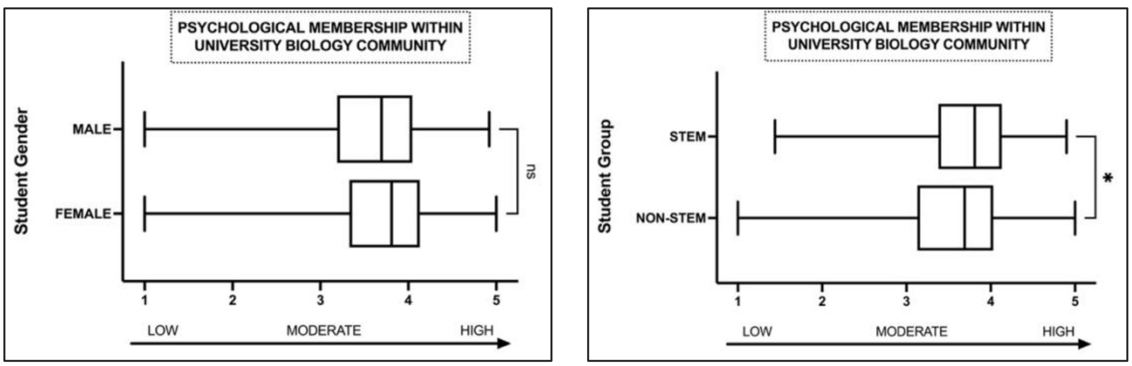


Figure 2. **Comparison of PSSM results by participant gender and group.** Students from the STEM group feel significantly more membership within the university biology community than non-STEM students do, but no significant difference in psychological membership was detected between men and women students.

Table 7. **Descriptive statistics and ANOVA summary table for PSSM scores**

Gender	Group	Mean	SD	N
Women	STEM	3.77	0.61	91
	non-STEM	3.65	0.79	80
Men	STEM	3.73	0.52	72
	non-STEM	3.51	0.74	40

Source of variation	df	SS	F	*P*
Group	1	4.07	1.73	**0.003**
Gender	1	1.81	17.10	**0.04**
Group:Gender	1	1.05	15.95	0.12
Residual (error)	279	122.7		
Total	282	128.0		

A two-way ANOVA with IAT score as the dependent variable and participant gender and group as the independent variables revealed a significant interaction effect of gender and group on IAT scores (Table 8). The mean IAT score for women STEM students (μ = 4.60, *SD* = 1.47) was the lowest of the four groups and suggests little/no automatic gender/science association (Figure 3). In contrast, men STEM students exhibited the strongest male/science automatic association of the four groups (μ = 5.43, *SD* = 1.44).

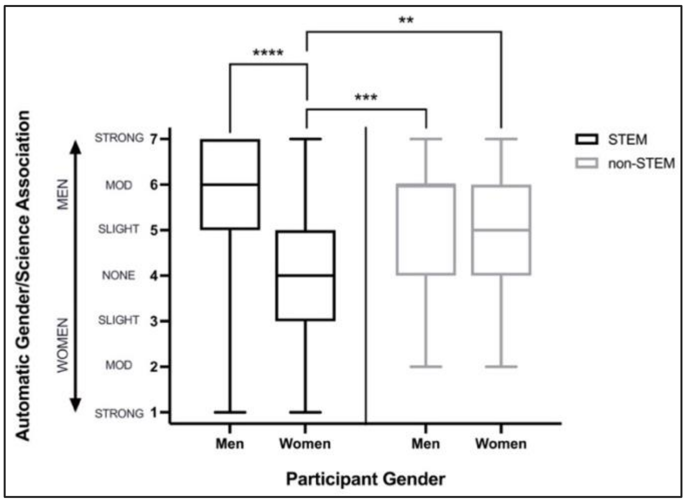


Figure 3. **Women STEM students have significantly lower IAT scores (less of an automatic association between men and science) and men STEM students show the highest automatic association between men and science.**

Table 8. **Descriptive statistics and ANOVA summary table for IAT scores**

Gender	Group	Mean	SD	N
Women	STEM	4.17	1.46	91
	non-STEM	5.10	1.33	80
Men	STEM	5.60	1.42	72
	non-STEM	5.13	1.44	40

Source of variation	df	SS	F	*P*
Group	1	3.44	1.73	0.19
Gender	1	34.05	17.10	**< 0.0001**
Group x Gender	1	31.75	15.95	**< 0.0001**
Residual (error)	279	555.4		
Total	282	644.6		

A one-way ANOVA found that mean BIO-ID scores differed significantly by IAT category ($F[2,284]=3.352$, $p = 0.036$); students with an automatic female/science association identified more strongly as a biologist ($\mu = 3.14$; $SD = 0.93$) than students with no automatic gender/science association ($\mu = 2.78$; $SD = 0.94$) or those with an automatic male/science association ($\mu = 2.77$; $SD = 0.92$). PSSM scores did not differ significantly by IAT category ($F[2,284]= 0.40$, $p = 0.67$).

STUDENT PERCEPTIONS OF NON-HUMAN ANIMALS

Student perceptions of non-human animals engaged in parental, intrasexual, and intersexual interactions are influenced by animal taxa and the image context provided.

PARENTAL INTERACTIONS

When viewing images depicting parental interactions, students sometimes suggested that the focal animal was participating in biparental care (i.e., they assumed that the other parent was also involved in caring for offspring). Given the same photograph, students who were told that the image they viewed depicted a male animal were significantly more likely to assume the occurrence of biparental care compared to students who were told that the animal was a female (Fisher's exact test, $p = 0.005$; Figure 4). Students who were not provided with any context were significantly more likely to assume that the focal parental animal was female for birds and mammals but were less likely to assume the sex of parental fish ($X^2[2,205] = 82.83$, $p < 0.0001$; Figure 5).

INTRASEXUAL INTERACTIONS

Two of the three intrasexual images viewed by students depicted females engaged in competition for mates. Although 34% of the students who were provided with no context about the sex of intrasexual competitors indicated that at least one of the

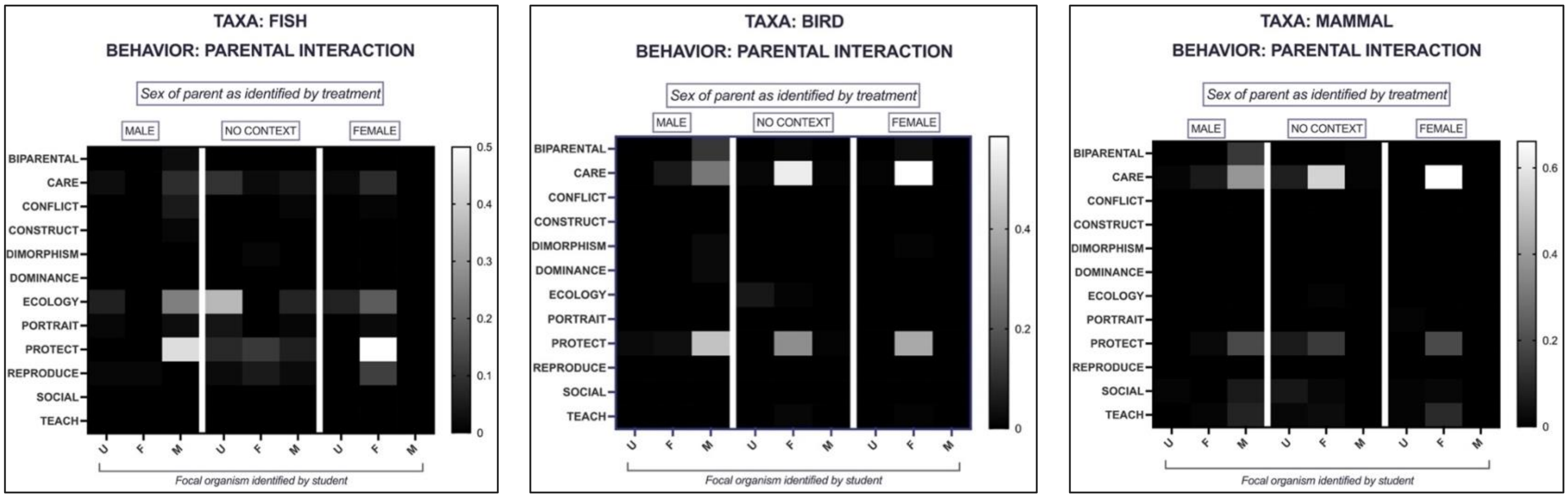


Figure 4. **Student perceptions of non-human animals pictured in parental interactions are influenced by the taxa depicted and context provided.** Significantly more of the students who were provided with "male parent" images (left-hand columns) assumed the occurrence of biparental care (13% of students) compared to the students who were provided with "female parent" images (right-hand columns, 5% of students; Fishers exact test, $p = 0.005$). Students who were not provided any context were significantly more likely to assume that parental birds and mammals were females, but typically refrained from making explicit assumptions about the sex of a parental fish

animals pictured was female, they never inferred that females were competing for access to mating opportunities (Figure 6). Rather, 16% of these students indicated that females were engaged in choosing a mate, and 11% indicated that females were engaged in biparental care.

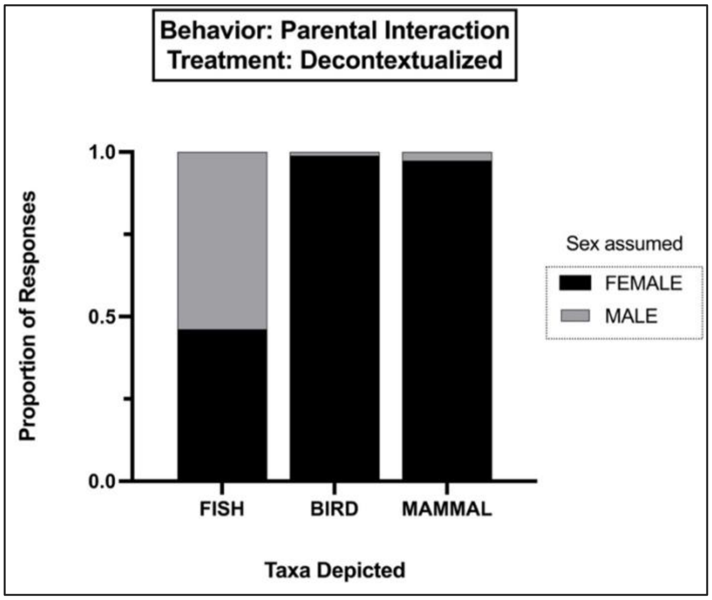


Figure 5. **Students who viewed decontextualized images depicting parental interactions were significantly more likely to assume that the focal parental animal was female for mammals and birds** (X^2[2,205] = 82.83, $p < 0.0001$)**.** This difference was not apparent for images of decontextualized fish.

Students who viewed images contextualizing females as competitors always described a more diverse array of activities with which to explain the behavior depicted (e.g., social interactions, competition for resources, etc.) than those who viewed images contextualizing males as competitors. For example, 14 themes emerged in student descriptions of images contextualizing female fish as competitors but only 9 themes emerged in student descriptions for the same image, depicting the same fish, only contextualized as males. Similarly, 10 themes emerged for female birds depicted as competitors compared with 7 themes for male birds, and 5 themes emerged for female mammals depicted as competitors compared with 4 themes for male mammals.

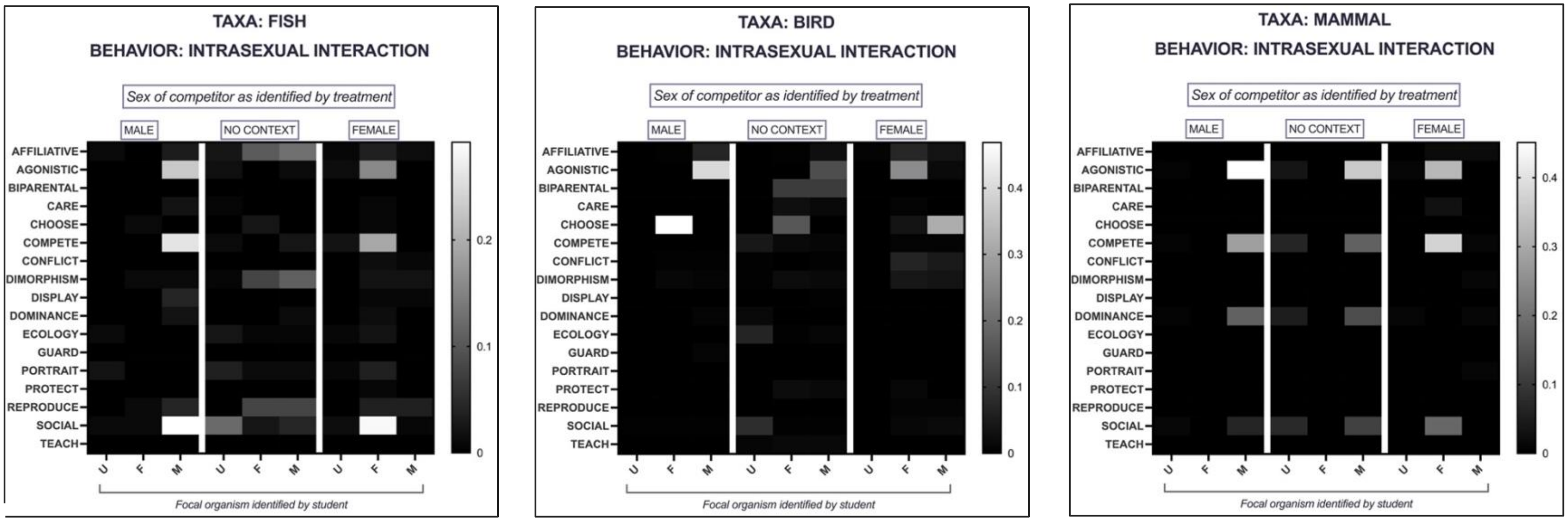


Figure 6. **Student perceptions of non-human animals pictured in intrasexual interactions are influenced by the taxa depicted and context provided.** Students who were provided with no context that indicated the sex of the competitors (middle columns) never assumed that females were competing for access to mating opportunities (i.e., the agonistic theme).

Intersexual Interactions

Students who were told that the image they viewed depicted a female courter were more resistant to describing male birds as choosers than male fish or mammals (Figure 7). Students who viewed images without context most often assumed that the affiliative images of birds and fish pictured choosy females and courting males. The affiliative mammal image depicted a female primate displaying sexual swelling ornamentation and seemed to confuse many students who viewed the image without context. Often students ascribed social, rather than affiliative, motivations for this behavior. Overall, students were significantly more likely to describe males as active, while females were more often described as passive or reactive ($X^2[4,3669]= 436.8$, $p <0.0001$).

References & Descriptors

Students with no automatic gender/science associations who viewed images without context were more likely to explicitly state that they could not determine the sex of the focal organism than students with automatic gender/science associations, but the difference was not significant ($X^2[2,344] = 5.13$, $p = 0.077$). However, the descriptors used for females differed significantly by IAT category ($X^2[4,1636] = 11.66$, $p = 0.02$). Students with automatic male/science associations most often described females as passive, those with automatic female/science associations most often described females as active, and those with no automatic gender/science associations most often described females as reactive (Figure 8).

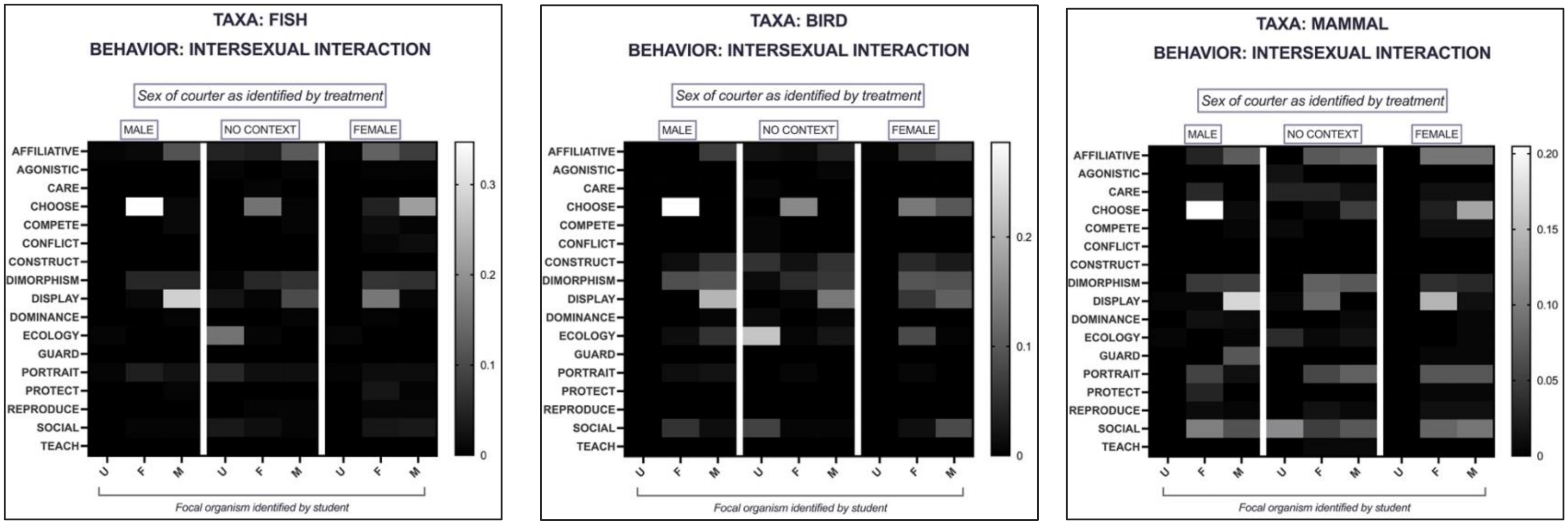


Figure 7. **Student perceptions of non-human animals pictured in intersexual interactions are influenced by the taxa depicted and context provided.** Students who were told that the image they viewed was of a female courter (right-hand columns) were more resistant to categorizing male birds as choosy than they were male fish or mammal

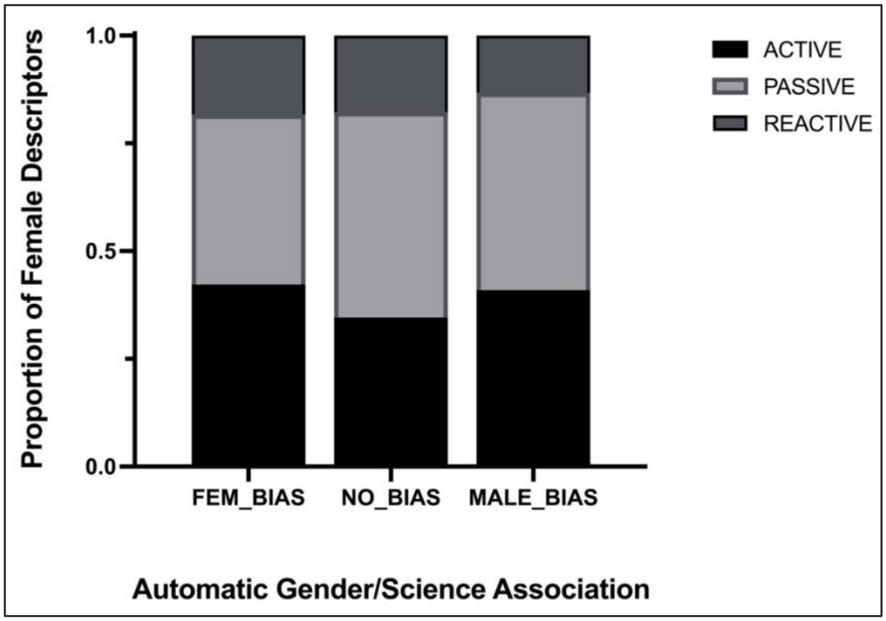


Figure 8. **Student perceptions of non-human animals pictured in intersexual interactions are influenced by the taxa depicted and context provided.** Students who were told that the image they viewed was of a female courter (right-hand columns) were more resistant to categorizing male birds as choosy than they were male fish.

DISCUSSION

The student descriptions of non-human animal behaviors examined in this study imply that many students internalize human sex/gender stereotypes and use them to [1] predict the sexes of non-human animals, and [2] explain the behaviors of non-human animals. In many ways, the descriptions provided by students reflected those used by textbook authors to describe similar images in biology textbooks.

Given the overwhelming presentation of classic sex roles in biology textbooks (Fuselier et al., 2018; chapter one), it is unsurprising that several students explicitly expressed confusion at contextualized images depicting expanded sex roles, for example, writing "*this was not what we learn in class*" and "*I didn't know males provided parental care in any animals.*" Students who viewed images contextualizing females as competitors always described a more diverse array of activities with which to explain the interaction pictured (e.g., social interactions, competition for resources, etc.), indicating that many students may harbor implicit gender essentialist beliefs and, as a result, struggle to conceptualize females as active agents engaged in competition for mates.

Similar to previous human image analysis studies, many students described non-human male animals as active and non-human female animals as passive or reactive. However, to my knowledge this is the first study to examine and elucidate a significant relationship between the automatic gender/science associations held by individuals and the language they use to depict non-human male animals as active and non-human female animals as passive or reactive. The pattern that emerged is simultaneously interesting and unsurprising- students with automatic female/science associations describe non-human female animals as active while students with no automatic gender-science associations describe female animals as reactive and those with automatic male/science associations female animals as passive.

The simplicity and sensical nature of it almost obscures its significance — from these data, this study has made an explicit connection between two implicit manifestations of essentialist perspectives. Additionally, it lends support to previous work documenting an anthropomorphic affiliation for more closely related taxa by demonstrating that students are more likely to apply human gender stereotypes to mammals and birds, for example, as opposed to fish. However, as the animal behavior textbook image analysis found that textbook authors emphasize classic sex roles using images of mammals and highlight expanded examples using images of fish, biology curriculum inadvertently reinforces negative human gender stereotypes by missing the opportunity to highlight variation and flexibility in species that students more relate to (i.e., mammals and birds).

As stereotypic attitudes and anthropomorphic tendencies are well-formed by the time an individual attends university, it would be an overreach to claim that this non-human manifestation of the hidden curriculum of gender bias is the perpetuator of essentialist beliefs in society. Additionally, the confusion on the part of students about some of the behaviors depicted may indicate a lack of prior knowledge about that type of animal or behavior and not necessarily indicative of a conflict in beliefs. However, to say that we are doing a disservice to our students is, perhaps, an understatement. As disciplinary experts of a field from which knowledge has been used to justify social injustices, it is of paramount importance that we endeavor to curate and communicate thoughtful and transparent messages that convey objective and accurate scientific knowledge.

CHAPTER FOUR

EXPANDING SEXUAL SELECTION INSTRUCTION: QUEERING AN INCONVENIENT DICHOTOMY

INTRODUCTION

One of the more socially consequential misuses of biology is the assertion that biological differences justify disparities in the equality of and/or achievements awarded to different groups of individuals. Specifically, the concept of *biological determinism* — the idea that behavior is a result of biological attributes, uninfluenced by environmental or sociocultural forces — has been used by those in power to rationalize conditions that perpetuate the oppression of individuals who are not members of the dominant group (Ahnesjö et al., 2020). One troubling manifestation of biological determinism is the endorsement of *gender essentialism* — the concept that differences in biology confer immutable differences to men and women. Traditional sex-role ideology has historically relegated women to the subordinate status of vulnerable, passive caregivers while concomitantly elevating men to the dominant status of protective, assertive providers (Larsen & Long, 1988). Fostered by the historical exclusion of women (and minorities) from participation in scientific inquiry, the perpetuation of gender essentialism risks biasing science knowledge construction with a heteronormative androcentrism (Ah-King & Ahnesjö, 2013).

In fact, anthropomorphic and sexist language (e.g., *rape*, *coy*) reflecting a view of stable genders in non-human animals abound in scientific depictions of *active* males and *reactive* females (David et al., 2001; Dougherty et al., 2013; Green & Madjidian, 2011; Martin, 1991; Wagner et al., 2010). Despite the inherent social inequities resulting from gender essentialist perspectives, scientific explanations presented to biology students often risk ascribing gendered societal norms and values to the motivations and interactions of both humans and non-human species (Ahnesjö et al., 2020; Ewald, 2016; Gowaty, 2017). This implicit manifestation of gender essentialism is of particular concern when students are taught about sexual selection, a theory proposed by Darwin (1871) to explain the evolution of seemingly deleterious traits and behaviors in sexually-reproducing species. The "textbook" example of an apparently maladaptive sexually-selected trait is the elaborate tail of male peafowl — an ornamental burden used by females to select the best among many competing males — which increases male attractiveness to females at the cost of increased conspicuousness to predators (Fuselier et al., 2018; Gadagkar, 2003). Although most undergraduate evolution curricula cover sexual selection, there are no studies investigating how university students conceptualize the theory (Ziadie & Andrews, 2018). Accordingly, the injustices risked by the implicit endorsement of gender essentialism through the presentation of sexual selection makes my research immediately significant to STEM pedagogy and epistemology.

AN INCONVENIENT DICHOTOMY

Biological determinism asserts that patterns of human behavior are a function of a person's biology rather than psychological or sociocultural forces or a combination thereof (Ahnesjö et al., 2020; Haslam et al., 2002). Historically, it provided a scientific basis for which moral arguments were made asserting the inferiority of underrepresented groups (e.g., women) and, subsequently, justifying their oppression (Ahnesjö et al., 2020). Determinism explains patterns of gendered behavior as a function of biology and is the scaffold upon which gender essentialist attitudes are constructed. Gender essentialism perpetuates an immutable and dichotomous depiction of human gender roles in which men act a certain way as a result of their testosterone levels and Y chromosome, whereas women act a distinctly different way as a result of their estrogen levels and *lack* of a Y chromosome (Amato & Booth, 1995; Klysing, 2020; Kray et al., 2017). However, the longstanding argument over the veracity of sex as a legitimate, dichotomous, and biological category has been complicated by the consideration of factors such as chromosomes, hormones, and internal versus external genitalia (Fausto-Sterling, 2019). In fact, many physiological and behavioral traits considered to be dichotomous demarcations of maleness or femaleness occur simultaneously within individuals and may change over time. Importantly, gendered structures have been shown to affect biological structures and vice versa, and neither are fixed traits that can be measured by a single, validated approach.

Feminist scholars have long emphasized that biological sex is not tantamount to gender identity, which Gowaty (2018) describes as a *process of becoming* that occurs over the course of a lifetime and is shaped by biological, psychological, and sociocultural forces. And yet, essentialist attitudes about "appropriate" gendered behaviors are known to manifest at a young age and increase in intensity over the course of an individual's lifetime through societal enculturation (Flerx et al., 1976; Reis & Wright, 1982). Men tend to hold more traditional beliefs about gender roles than women and are more likely to consider these roles to be inflexible, a pattern that is also observed when comparing gender essentialist attitudes of individuals endorsing conservative versus liberal political ideologies (Eidlin, 1981; Kray et al., 2017). Perhaps most problematically, essentialist perspectives perpetuate social injustices, as the endorsement of gender essentialism relates to both the endorsement of discriminatory practices towards women and to the maintenance of gender status inequalities (Morton et al., 2009). Although societal perceptions of gender roles have shifted in recent decades, this change is most noticeable within the labor force; in other words, the extent to which women occupy professional roles eclipses that to which men occupy domestic roles (Bianchi et al., 2014; Bianchi & Milkie, 2010; Diekman & Eagly, 2000; Lueptow et al., 1995). In fact, despite their increased presence in the work force, women are paid less than men for the same job and are less likely to hold supervisory positions (Ridgeway, 2009). Additionally, although women now earn a majority of the PhDs awarded in many of the academic sciences, they compose only 25 percent of postdoctoral fellowships and competitive faculty grants (Goulden et al., 2011). This reflects a remarkable drop in the progressive representation of women through the professional ranks of the STEM academe, and surveys of postdoctoral women indicate that this may be attributed in part to domestic pressures (e.g., familial concerns like child-rearing; (Simon et al., 2017). Thus, consideration of how human gender stereotypes are perpetuated in biology curricula is both timely and important, as examples used to teach theories such as evolution by sexual selection may communicate and reinforce implicit gender stereotypes that contribute to the disenfranchisement of women in both society and scientific endeavors (Fuselier et al., 2018; NRC, 2010).

THE DESCENT OF [WO]MAN

Darwin (1871) proposed the theory of sexual selection as an evolutionary mechanism to explain costly traits such as exaggerated armaments (e.g., moose antlers), which he believed arose as a consequence of physical competition between males for access to mates, and elaborate ornaments (e.g., peacock trains), which he believed were a result of female preferences for aesthetic beauty. However, the notion of *female choice* was antithetical to the commonly held beliefs of the 19th century that females were less evolved, less intelligent, less complex, less aggressive, and less interested in sex than their male counterparts (Tang-Martinez, 2016). As such, sexual selection theory received little attention from the scientific community until the middle of the 20th century, when Darwin's ideas were expanded upon by empirical works investigating [1] variance in reproductive success between the sexes (Bateman, 1948); [2] the relationship between anisogamy (i.e., gametes differing in size and/or form) and parental investment (Trivers, 1972); and [3] the influence of the ratio of sexually reproducing males versus sexually reproducing females (Emlen & Oring, 2007). Taken together, these studies form the foundation of the classic sexual selection paradigm, which implies that [1] sexual selection typically acts on males via differential success within *affiliative* interactions (i.e., attraction) and/or *agonistic* interactions (i.e., competition), and [2] a positive relationship exists between a male's (but not female's) reproductive success and the number of mates it acquires.

Darwin's original conception of sexual selection and the subsequent research undertaken to test it are particularly ripe for a gender essentialist interpretation, as valid concerns have been raised with the theoretical assumptions and methodologies that scaffold classic sexual selection theory (Altmann, 2009; Rowell, 1967; Tang-Martinez, 2016). Critics of the classic understanding suggest that a more inclusive, variable, and *expanded* version of sexual selection highlighting variation in reproductive tactics is more accurate (Tang-Martínez, 2016) and cite numerous examples of species that exhibit traits seemingly contradictory to the traditional understanding of sexual selection and early assumptions of the theory. For example, genetic analyses of mammalian litters and avian clutches revealed that polyandry and extra-pair copulations were sufficiently ubiquitous to require a distinction between sexual and social monogamy (Dunn & Lifjeld, 1994; Stamps, 1997; Carter et al., 1995), and females of some animal species (e.g., meerkats) have been shown to compete for access to mating opportunities despite investing considerable energy and resources into caring for their offspring (Clutton-Brock, 2007, 2017; West-Eberhard, 1983). Other notable examples that depict a more realistic and "expanded" picture of sexual selection include species with ornamented, polyandrous females (e.g., red phalaropes) and those exhibiting biparental care (e.g., cleaner wrasses) and mutual mate choice (e.g., fruit flies; Amundsen, 2000; Kraaijeveld et al., 2007; Tang-Martinez, 2016).

Although evolutionary biology textbooks acknowledge the diverse criticisms of sexual selection — for example, by citing the influence of feminist critique and including examples of expanded sexual selection concepts (Fuselier et al., 2016) — they largely emphasize the classic conceptualization and both text and images have an androcentric bias (Fuselier at al., 2018). Because educators use textbooks to structure their curriculum and frame the knowledge of a discipline (Hogben & Waterman, 1997; Sánchez & Belmar, 2006) and sexual selection theory has been applied to humans (Wilson et al., 2017), this risks the implicit reinforcement of gender stereotypes in science classrooms and the continued enculturation of false essentialist perspectives that are known to perpetuate social injustices (Brown & Stone, 2016; Kuchynka et al., 2018).

GENDERED LANGUAGE

One reason that expanded examples of sexual selection have been largely overlooked may be that our conceptions of gender in humans and our tendency to anthropomorphize influence how we view non-human animals (Ewald, 2016). In the broadest sense, anthropomorphism can be defined as [a] *the attribution of human characteristics to that which is not human* (Epley et al., 2007); this study was informed by an ethological iteration of the concept, [b] *the supposition that animals' behaviors are driven by motives similar to those of humans* (Urquiza-Haas & Kotrschal, 2015). Scientists often explicitly discourage the inclusion of anthropomorphic and teleological explanations of evolutionary phenomena to mitigate unconscious bias in scientific discourse (Dacey, 2017); still, our experiences and limitations as humans inevitably color the sex-specific assumptions, predictions, and interpretations that we make about animal behavior (Ahnesjö et al., 2020). In some cases, anthropomorphisms may enhance the understanding of animal behavior (Epley et al., 2007); however, unexamined anthropomorphic perspectives have the potential to influence what questions are asked, which hypotheses are generated, and how data are interpreted in science (Dacey, 2017; Davies, 2010). For example, sexist and anthropomorphic terminology is often used in scientific explanations to both humanize non-human female animals through gendered narratives of nurturing maternal care and frame males in a dominant and possessive light (Ewald, 2016; Fuselier et al., 2018). Such gendered and anthropomorphic depictions of animal sex roles by the scientific community fail to reflect the variation and flexibility of sexual-selection-related concepts (e.g., male parental care, female signaling; (Jackson, 2014) and risk disseminating biased assumptions about the conscious mental intent of non-human animals (Watson, 1913) and communicating an implicit, yet authoritative, scientific endorsement of gender essentialism. Accordingly, the use of anthropomorphisms in association with sexual selection has been criticized for promoting a heteronormative narrative that both [1] fails to reflect the incredible diversity and flexibility of reproductive behaviors and interactions of males and females in a wide variety of taxa (Tang-Martinez, 2016), and [2] espouses a supposedly veridical *competitive males and choosy females* dualism that functions to buttress the dominant patriarchal and gender-stereotypic discourse shaped by societal and cultural norms (Ah-King & Ahnesjö, 2013).

THEORETICAL FRAMEWORK

This study adopted tenets of queer curriculum theory [QCT] (Sumara & Davis, 1999) as a guiding theoretical framework for my presentation of sexual selection and examination of student understanding of sexual selection related concepts. QCT is related to both feminist and queer theories (Gedro & Mizzi, 2014) and addresses how gender and sexuality are reflected in the production of knowledge (Sumara & Davis, 1999). Notably, QCT endorses equity and fluidity in discourse production and problematizes static identity-categories (e.g., male/female or gay/straight), citing evidence that suggests that the relationship between an individual's biological and phenomenological identity is in a state of constant flux (Ah-King & Nylin, 2010; Sumara & Davis, 1999). This is particularly salient for work on sexual selection, where sex roles have traditionally been viewed as immutable manifestations of biological characteristics (i.e., gender expression = biological sex). Importantly, the framework of QCT offers an approach for refining educational practices to facilitate inclusive, meaningful and supportive initiatives for all students regardless of gender identity or sexual orientation by raising awareness of biased, value-laden, and heteromasculine practices within academia and endorsing a more fluid concept of gender and sexuality that enriches our understanding of diversity (Broadway, 2011; Sumara & Davis, 1999).

Feminist and queer theory initiatives were born of the need to understand and mitigate the systemic oppression and disenfranchisement of certain groups in society (Gedro & Mizzi, 2014). In order to interrupt heteronormative thinking and the problems stemming from it, QCT encourages educators to focus less on the presentation of existing knowledge and instead emphasize inquiry into how knowledge is constructed, and by whom. This approach offers an improved system of checks and balances for revealing and avoiding biases, as QCT advocates for the integration of social and rational aspects of science and the transparent portrayal of scientific epistemology as a function of lived, subjective, and social (i.e., intersectional) experiences colored by historical context (Broadway, 2011). Incorporating the tenets of this framework into curriculum development may provide science educators with a rewarding methodology for communicating a biological phenomenology that encourages the genesis of diverse student ideas and identities through the production of inclusive and meaningful knowledge (Longino, 2002; Broadway, 2011; Fuselier et al. 2016). The application of QCT to STEM pedagogy — particularly for concepts addressing biological sex, gender, sexuality, and reproduction — encourages educators to address how the historical application of anthropomorphic gendered stereotypes has shaped research methodology and the creation of scientific knowledge and may promote a discourse that calls into question the validity of gender essentialist beliefs.

PURPOSE OF STUDY

This study examines student understanding of sexual selection related concepts and investigates relationships between the presentation and conception of sexual selection and the gender essentialist perspectives held by undergraduate students. I created a content assessment to investigate how students understand concepts related to sexual selection when presented with a "classic" view of the theory (emphasizing static sex roles and the androcentric paradigm) versus an updated, "expanded" view of the theory (emphasizing variation and the flexible nature of reproductive interactions). My overarching objectives were to [1] examine relationships between gender essentialist attitudes held by students and their conceptualizations of sexual selection, and [2] determine whether the presentation of classic versus expanded views of sexual selection has an impact on student understanding of the theory. For both STEM and non-STEM undergraduate majors I asked:

[1]: Do undergraduate students hold gender essentialist perspectives? If so, what patterns emerge among their beliefs?

[2]: Do the types of sexual selection examples presented to students influence their understanding of the theory?

[3]: Do students' gender or essentialist perspectives influence their understanding of sexual selection theory?

[4]: Do gender stereotypes and anthropomorphic language suggestive of gender bias appear in student writing about sexual selection?

I expected that the endorsement of a biological theory of gender would be positively related to support for traditional sex roles and political conservatism, while the endorsement of a social theory of gender would positively relate to support for egalitarian sex roles and liberalism. I expected that STEM students would outperform non-STEM students on the content assessment but predicted that the presentation of complex examples of sexual selection focused on expanded views — as opposed to classic views — would facilitate student understanding of the wide variety of ways in which sexual selection operates and that this would be reflected in quantitative assessment scores and the quality of written responses across both groups of students. I also expected that participants with more essentialist attitudes would struggle with conceptualizing expanded sexual selection concepts, and that misconceptions about the theory might indicate limits in thinking about the targets of sexual selection (e.g., sexual selection acts on or is driven by males, but not females). Finally, I anticipated that students who used anthropomorphic and gender-stereotypic language when writing about sexual selection in non-human animals would demonstrate a more limited understanding of the theory.

METHODS

STUDY POPULATION

This project took place at the University of Louisville and received IRB approval (RB 18.0028). Study participants were recruited from Biology classes and were offered in-class points for completing an assessment designed for my study. Participant demographics reflected those of the larger university population; 64% identified as women, and 68% as white (Table S1). Responses from individuals meeting exclusionary criteria were removed prior to analyses (Table S2), leaving data from 319 undergraduate students for investigation, 145 of whom were recruited from one of eleven different upper-level Biology courses (hereafter the *STEM* group), and 174 of whom were recruited from one of three sections of an introductory-level non-majors Biology course (hereafter the *non-STEM* group). Participants sorted into the STEM group identified a STEM-related field as their major area of study, were mostly in their third or fourth year of college, and were recruited from a variety of 300, 400, and 500-level biology courses offered to science majors who have successfully completed several lower-level biology prerequisites. Students sorted into the non-STEM group were non-STEM majors mostly in their first or second year of college and were recruited from a non-majors Introductory Biology course that satisfies a general education requirement and has no prerequisite course requirements.

On average, STEM students had successfully completed more than 5 college biology classes prior to taking part in my study, whereas all non-STEM students enrolled in their first college biology class were at the time of data collection. Study participants selected their gender from a list of choices (*male*, *female*, *nonbinary*, and *other*), self-reported political ideology on a scale from 1-5 (where 1 = *extremely liberal* and 5 = *extremely conservative*) and answered an open-response question about race/ethnicity. Although women comprised the majority of both groups, the proportion of women in the non-STEM group was significantly higher than that in the STEM group (X^2[1,319]=10.66, *p*=0.0011). Additionally, the distribution of ethnicities across the two groups was different (X^2[5,319]=13.93, *p*=0.0161); specifically, a higher percentage of students who self-identified as Asian (12.4%) were in the STEM group (vs. 2.3% for the non-STEM group) while a higher percentage of students who self-identified as Black (10.3%) were in the non-STEM group (vs. 6.8% for the STEM group).

MEASURING GENDER ESSENTIALIST BELIEFS

Participants responded to questions from two published surveys designed to investigate distinct aspects of gender-essentialist beliefs. The Gender Theories Questionnaire [GTQ] (Coleman & Hong, 2008) is a 6-point scale (where 1 = *strongly disagree* and 6 = *strongly agree*) with 11 statements developed to evaluate an individual's endorsement of a biological and/or social theory of gender. Participants received two distinct GTQ scores (i.e. GTQ-Biological & GTQ-Social) ranging from 1 (*little/no theory endorsement*) to 6 (*full theory endorsement*). The Traditional-Egalitarian Sex Role Scale [TESR] (Larsen & Long, 1988) uses a Likert scale (where 1 = *strongly disagree* and 5 = *strongly agree*) with 20 statements designed to measure attitudes about traditional versus egalitarian sex roles. Participants were asked to rate their level of agreement with ten statements keyed in a traditional and ten keyed in an egalitarian direction. For this study participants received a single TESR score with scores closer to 1 considered to indicate strongly traditional views about sex roles and scores closer to 5 considered to indicate strongly egalitarian views.

Scores from the GTQ, TESR, and self-reported political data were analyzed in a Principal Components Analysis [PCA] to develop a single composite measure of gender essentialism. PCA is useful in this aspect as it reduces dimensionality of large datasets while retaining variation and allowing for easy visualization of strong patterns among active variables and supplementary variables of interest. The active variables included in the PCA were participant [1] TESR scores, [2] GTQ-Biological scores, [3] GTQ-Social scores, and [4] political ideology rating. Supplemental variables included in the PCA were participant [1] gender, [2] STEM versus non-STEM group, and [3] instructional condition. I identified and interpreted principal components with the highest explanatory power and evaluated axis scores for their use as composite measures of gender essentialism (hereafter, *GE scores*), and hierarchical clustering analysis was used to generate categories of students sharing conceptual models of GE beliefs (hereafter, *GE clusters*) for use in subsequent analyses.

Classic versus Expanded instructional conditions

To examine whether the presentation of classic versus expanded examples of sexual selection influence understanding of the theory, students were randomly assigned to one of two treatments: either a "classic" or an "expanded" sexual selection lesson that was viewed entirely online. Lessons began with a short preamble that [1] defined relevant terms (e.g., fitness, selection, fecundity, etc.), and [2] described the basic tenets of both natural and sexual selection. Participants were then presented with a sequence of images and text illustrating four biologically accurate examples of selection that were typical of those encountered in college biology textbooks *and* reflective of a student's assigned treatment. Consistent across each lesson were: [1] the introductory preamble, [2] the animal taxa used to illustrate a concept (i.e., two mammals, one bird, and one fish), [3] the order in which taxa were presented, [4] the word count and level of detail included in the text description of the examples, and [5] the surveys presented following the assessment. The instructional conditions differed in the types of sexual selection examples that were presented (Table 1). Students assigned to the classic instructional treatment (n = 146) were presented with three examples highlighting the "classic" and one highlighting the "expanded" view of sexual selection (in the order *classic, classic, expanded, classic*). This treatment mirrored the presentation of sexual selection in textbooks (Fuselier et al., 2016). The expanded instructional treatment presented students (n = 173) with three "expanded" and one "classic" example of sexual selection (in the order *expanded, expanded, classic, expanded*).

Table 1. ***Examples and concepts presented to students assigned to the classic and expanded instructional conditions***

Instructional Condition	Selection Type	Example Species	Sexual Selection Concept
Classic	Classic	Sage grouse	Choosy females
	Classic	Guppies	Male ornamentation
	Expanded	Prairie dogs	Female fitness
	Classic	Elephant seals	Male competition
Expanded	Expanded	Dotterels	Female competition
	Expanded	Gobies	Flexible sex roles
	Classic	Elephant seals	Male competition
	Expanded	Prairie dogs	Female fitness

EXAMINING STUDENT UNDERSTANDING OF SEXUAL SELECTION

Following the lesson, all participants completed a content assessment, formatted to display one question at a time and prevent students from viewing or editing their answer after moving on to the next question. The test consisted of a series of four multiple-choice questions about natural selection, five multiple-choice questions about sexual selection, and one multiple-part question in which students were required to apply their knowledge to a novel example of sexual selection illustrating flexibility in katydid sex roles (hereafter, the *katydid question*).

The katydid question (Table 2) began with a short paragraph that explicitly described the mating behavior of katydids as both flexible and resource-dependent (Simmons, 1995). Two multiple-choice questions [8a & 8c] asked students to identify conditions under which either male or female katydids would be choosy, and students were then directed to provide written justification for their answers [8b & 8d]. For the final part of the katydid question [8e], students were asked to synthesize their knowledge by providing a written description of katydid sex roles. Questions about natural selection were drawn from the CINS (Anderson et al., 2002) and were included in the assessment to cloud the nature of the study (i.e., prior to consenting, participants were informed that the study was investigating how students understand evolution by selection, but not specifically *sexual* selection).

Questions about sexual selection were developed using end-of-chapter review questions found in college-level evolutionary biology textbooks. Assessment items were scored as 1 point for each correct answer with the exception of part 8e of the katydid question, which was scored using a rubric developed *a posteriori* based on content

Table 2. **The katydid question.**

In many katydids (insects), the male delivers his sperm to the female in a large spermatophore which contains nutrients that the female eats. Gwynn & Simmons (1990) studied behavior of caged katydids under low-food and high-food conditions. They measured how many males make a special mating call (chirping sounds), the number of matings per female, the number of instances of female-female competition for matings, the percentage of times a male rejected mating with a female, and the percentage of time a female rejected mating with a male.

Question Part	Question Type	Text	Answer
[a]	MC	Under which conditions would you expect the male to be more choosy about the female with whom he will mate?	**(a) low-food** (b) high-food
[b]	SA	Why?	[a] Cost & [b] fitness
[c]	MC	Under which conditions would you expect the female to be more choosy about the male with whom she will mate?	(a) low-food **(b) high-food**
[d]	SA	Why?	[c] Resource & [b] fitness
[e]	SA	Overall, given the description of katydid behavior and your answers to the previous questions, how would you describe the sex roles of male and female katydids?	See rubric

Note. Students were presented with all parts of the question simultaneously. MC = multiple choice question; correct answers are identified in bold. SA = short answer question. [a] Cost refers to the energetic expense of spermatophore production. [b] Fitness refers to the goal of increasing reproductive fitness by selecting the best male or female mating partner. [c] Resource refers the release of females from competition for nutritious spermatophores.

analysis of student written responses, and subsequently analyzed as a separate response variable.

Discriminability of the assessment was examined using a point biserial [Rpbi] correlation for multiple-choice questions and Pearson's [R] correlation for short-answer responses. Values can range from -1.00 to 1.00, and values $\geq$ 0.15 indicate that a question sufficiently discriminates between high-performing and low-performing students (Varma, 2006). Reliability of multiple-choice questions was measured using the Kuder-Richardson Formula 20 [KR-20], the recommended statistic for evaluating questions with dichotomous (e.g., right or wrong) answer choices (Bartko, 1978). Values can range from 0.00 to 1.00; higher values indicate reliability, but values in excess of 0.90 indicate the test is homogenous.

Reliability of short-answer responses was assessed with McDonald's omega [ω], as the data were found to violate the assumption of tau equivalence required for Cronbach's alpha (McNeish, 2018). Discriminability, difficulty, and reliability were evaluated for all test items using the combined assessment scores of students from all groups and treatments. Potential misconceptions about sexual selection were probed by identifying the incorrect answers selected by more than 20% of participants for a given multiple choice question (Smith & Knight, 2012) and by qualitative content analysis of written responses.

Best subsets regression analyses were used to evaluate the influence of variables (i.e., group, instructional condition, gender, and GE scores) on participant assessment scores (i.e., total assessment score and katydid score) and to elucidate the best model for explaining variation in test scores. Differences in language use types (i.e., NO/YES for stereotypic or anthropomorphic language) were compared via chi-square and Fisher's exact tests. All test items discriminated between low and high scoring students (Rpbi > 0.25; Varma, 2006), and reliability coefficient values for multiple-choice and short-answer questions indicated that the test was reliable (McNeish, 2018).

RESULTS

GENDER ESSENTIALIST BELIEFS IN UNDERGRADUATE STUDENTS

I obtained a quantitative measure of student gender essentialism scores [GE scores] by analyzing scores from the GTQ, TESR, and self-reported political data in a Principal Components Analysis [PCA]. The first dimension [Dim 1] of the PCA explained 59.33% of the variance (Figure 1) and each of the four variables (i.e. GTQ-Social, GTQ-Biological, TESR, and political ideology) contributed in roughly equal measure to this dimension (Table 3). As Dim 1 was the only principal component with an eigenvalue greater than 1 (EV=2.37), the decision was made to restrict further analyses to this dimension.

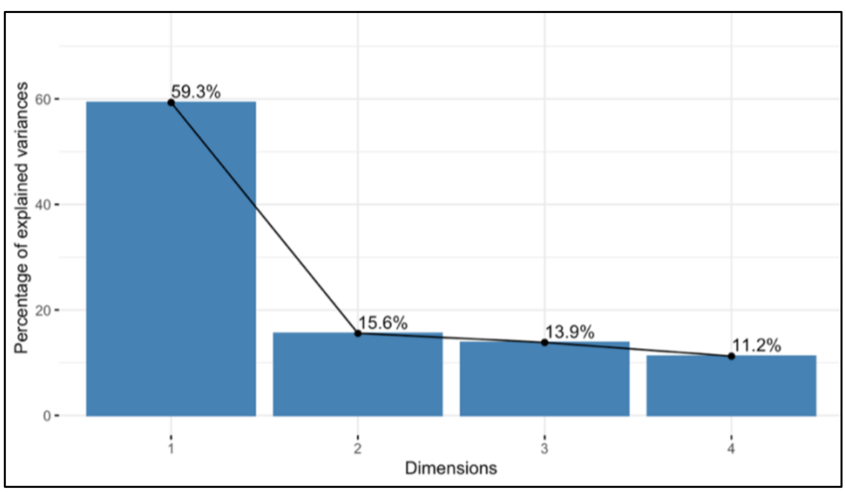


Figure 1. **Skree plot displaying the variance explained across dimensions 1 through 4 for Principal Components Analysis of student political ideology, gender theory endorsement (social/biological), and sex role beliefs.**

I predicted that the endorsement of a biological theory of gender would be positively related to support for traditional sex roles and conservative ideology, while the endorsement of a social theory of gender would positively relate to support for egalitarian sex roles and liberal ideology. As predicted, my PCA neatly opposes individuals based on political ideology, TESR, and gender theory endorsement (Figure 2). Participants who scored low on Dim 1 were associated with *conservative* political ideology and endorsement of *traditional* sex roles and a *biological* theory of gender, intermediate-scoring individuals were associated with *moderate* politics and endorsed *egalitarian* sex roles and a *biological* theory of gender, and those who scored high on Dim 1 were associated with *liberal* politics and endorsed *egalitarian* sex roles and a *social* theory of gender.

Table 3. **Summary statistics for dimensions 1-4 of Principal Components Analysis (PCA) examining relationships among distinct components of gender essentialist perspectives in undergraduate students.**

Principal Component	Eigenvalue	Variance (%)	Cumulative Variance (%)
Dim 1	2.37	59.33	59.33
Dim 2	0.62	15.58	74.91
Dim 3	0.55	13.85	88.76
Dim 4	0.45	11.24	100.00

Quality of representation (cos2) and percent contribution (%) for active PCA variables on Dim 1

Variable	cos2	%
[a] Politics	0.6163	25.97
[b] TESR Score	0.5987	25.23
[c] GTQ-Social Score	0.5983	25.21
[d] GTQ-Biological Score	0.5598	23.59

[a] Politics represents self-reported political ideology, selected on a Likert-scale where 1 = extremely liberal and 5 = extremely conservative. [b] TESR Score represents the quantitative score a participant received on the Traditional-Egalitarian Sex Role survey indicating the extent to which they support traditional or egalitarian sex roles. [c] GTQ-Social Score represents a quantitative measure of a participant's endorsement of a social theory of gender, based on their responses to the Gender Theories Questionnaire. [d] GTQ-Biological Score represents a quantitative measure of a participant's endorsement of a biological theory of gender, based on their responses to the Gender Theories Questionnaire.

The justification for using participant scores on Dim 1 as GE scores (i.e., a quantitative measure of gender essentialism) is two-fold. First, studies have shown that men are often more politically conservative than women and also hold more traditional views about sex roles than women do (Lee et al., 2011; Lye & Waldron, 1997). A t-test with participant dimension 1 scores as the dependent variable revealed that women (μ =0.31, *SD*=1.34) demonstrated higher ascription to liberal ideology and the endorsement of social gender theory and egalitarian sex roles compared to men (μ =-0.55, *SD*=1.72; $t[317]=4.96$, $p<0.0001$ [two-tailed]). Second, liberalism and the endorsement of a social theory of gender and egalitarian sex roles are known to correlate with less essentialist beliefs, while conservative ideology and the support of a biological theory of gender and traditional sex roles are known to correlate with more essentialist beliefs (Lye & Waldron, 1997; Martin & Parker, 1995; Unger, 1979).

Hierarchical clustering analysis of the PCA coordinates revealed three distinct clusters (hereafter *GE clusters*) of students grouped by shared political ideology, gender role perspectives, and gender theory endorsement (Figure 3, Table 4). The CTB cluster (n = 68) was composed of individuals who identified as politically *conservative* [C], expressed support for *traditional* [T] sex roles, and endorsed a *biological* [B] theory of gender. The MEB cluster (n = 153) was composed of individuals who identified as politically *moderate* [M], expressed support for *egalitarian* [E] sex roles, and endorsed a *biological* [B] theory of gender. Finally, the LES cluster (n = 97) was composed individuals who identified as politically *liberal* [L], expressed support for *egalitarian* [E] sex roles and endorsed a *social* [S] theory of gender.

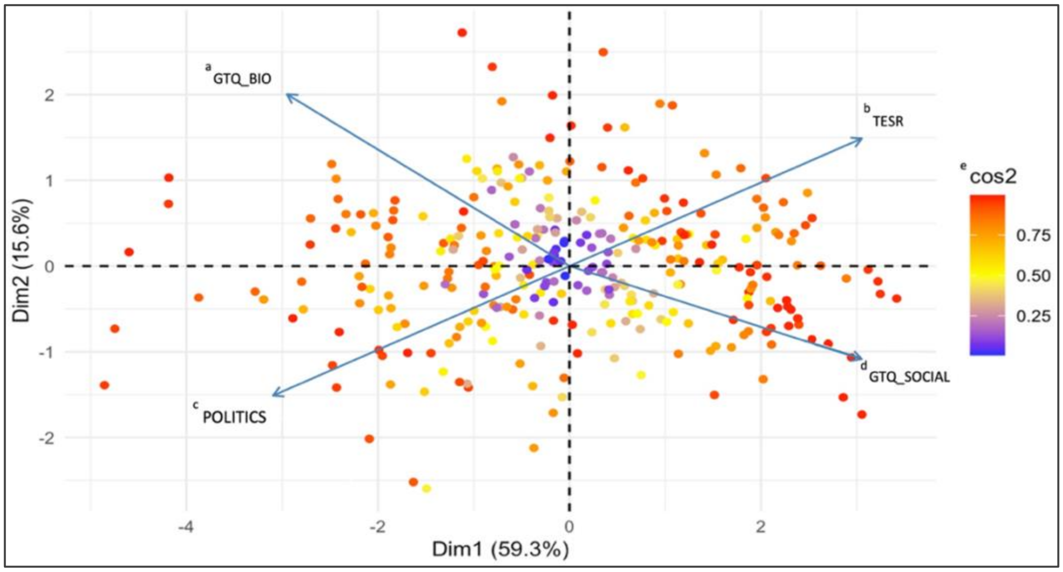


Figure 2. **Biplot projection of multivariate dataset across dimensions 1 and 2 of Principal Components Analysis (PCA) examining relationships among distinct components of gender essentialist perspectives in undergraduate students.** *Line length approximates variable variance, and line angles approximate variable correlations. Point distances approximate Euclidean distances between observations in multivariate space. [a] GTQ_BIO represents participant endorsement of a biological theory of gender endorsement, calculated from responses on the gender theories questionnaire. [b] TESR represents participant support for traditional or egalitarian sex roles, calculated from responses on the traditional-egalitarian sex role scale. [c] GTQ_SOCIAL represents participant endorsement of a social gender theory, calculated from responses on the gender theories questionnaire. [d] POLITICS represents participant reported political ideology. [e] cos2 represents the quality of representation of the variables on the map.*

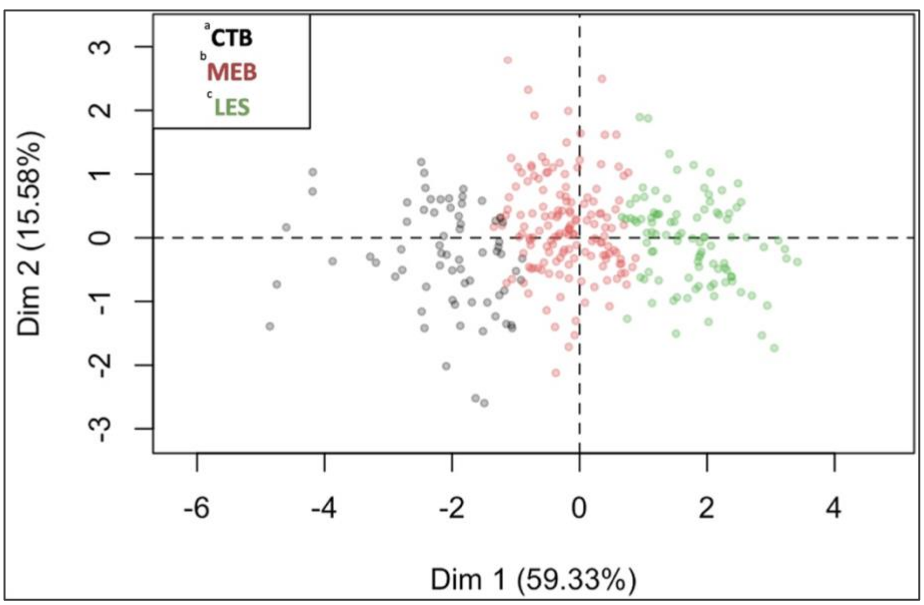


Figure 3. **Clusters of gender essentialist perspectives in undergraduate students.** Students scoring high on dimension 1 were considered as having less essentialist beliefs; students scoring low on dimension 1 were considered as having more essentialist beliefs. CTB: conservative, traditional, biological gender. MEB: moderate, egalitarian, biological gender. LES: liberal, egalitarian, social gender.

Table 4. **Summary statistics for GE Clusters by active PCA variables.**

GE Cluster	Variable	v-test	Mean	SD	p-value
CTB	Politics	9.39	1.01	0.70	****
	GTQ-Biological	7.94	0.85	0.98	****
	GTQ-Social	-8.24	-0.89	0.77	****
	TESR	-13.52	-1.45	0.85	****
MEB	TESR	3.24	0.19	0.59	**
	Politics	3.16	0.18	0.69	**
	GTQ-Biological	2.39	0.14	0.74	*
	GTQ-Social	-4.43	-0.26	0.69	****
LES	GTQ-Social	12.11	1.02	0.64	****
	TESR	8.50	0.71	0.41	****
	GTQ-Biological	-9.63	-0.81	0.74	****
	Politics	-11.76	-0.99	0.65	****

*$p < .05$. **$p < .01$. ***$p < .001$. ****$p < 0.0001$.

STUDENT UNDERSTANDING OF SEXUAL SELECTION THEORY

I anticipated that any alternative conceptions detected among undergraduates about sexual selection might indicate limits in student thinking about the targets of sexual selection (e.g., sexual selection acts on or is driven by males, but not females). However, analyses of student answers on multiple-choice questions indicate that students often confuse natural and sexual selection and struggle with the concept of behavioral flexibility in reproductive interactions. For example, although sexual selection involves the reproductive decisions made by the sexes of a species and how these decisions impact fitness, 22% of non-STEM (and 17% of STEM) students indicated that evolution by sexual selection occurs when one sex survives better than the other and contributes more offspring to the next generation. Additionally, although mate choice can be exhibited by males only, females only, or both sexes, 33% of non-STEM participants and 20% of STEM participants indicated that mate choice is exhibited by *males and females* (rather than *males only, females only, or both sexes*). Chi-square analyses revealed that participants in the MEB cluster were significantly more likely to choose this incorrect answer than were CTB or LES participants (X^2[8,319]=32.64, p<0.0001). Participants who received the classic instructional condition were more likely to indicate that mate choice is exhibited by *males only or females only, but never both* compared to those who received the expanded treatment (X^2[3,319]=12.68, p=0.0054). Best subsets regression used to evaluate the influence of predictor variables (i.e., STEM vs. non-STEM group, classic vs. expanded instructional conditions, participant gender, and GE scores) on total assessment scores revealed that participant group explained most of the variation in scores (Table 5, Figure 4a); however, the regression analysis also found that interaction effects between participant gender, instructional condition, and GE scores significantly contributed to the strength of the model. Specifically, participants with lower levels of

Table 5. **Output for best model produced by subsets regression examining effects of participant group, gender, instructional condition, GE scores and interactions on total assessment score.**

Explanatory Variable	Estimate	SE	t-value	p-value
Intercept	-0.29	0.20	-1.43	
STEM	0.59	0.27	2.18	*
Women	-0.26	0.23	-1.14	
Expanded	-0.14	0.21	-0.68	
Men : GE	0.01	0.08	0.08	
Women : GE	0.18	0.07	2.52	*
Expanded : GE	0.07	0.10	0.65	
STEM : Women	0.46	0.33	1.38	
nonSTEM : Men : Expanded	0.40	0.36	1.11	
STEM : Men : Expanded	0.31	0.32	0.97	
nonSTEM : Women : Expanded	0.37	0.27	1.38	
Women : Expanded : GE	-0.24	0.14	-1.70	

R-squared	0.19
F-statistic	6.65 (11,307)
p-value	5.95×10^{-10}

*p < .05.

essentialist beliefs typically scored higher on the assessment but this trend appeared to be stronger for women (Figure 4b) and students presented with the classic instructional treatment (Figure 4c).

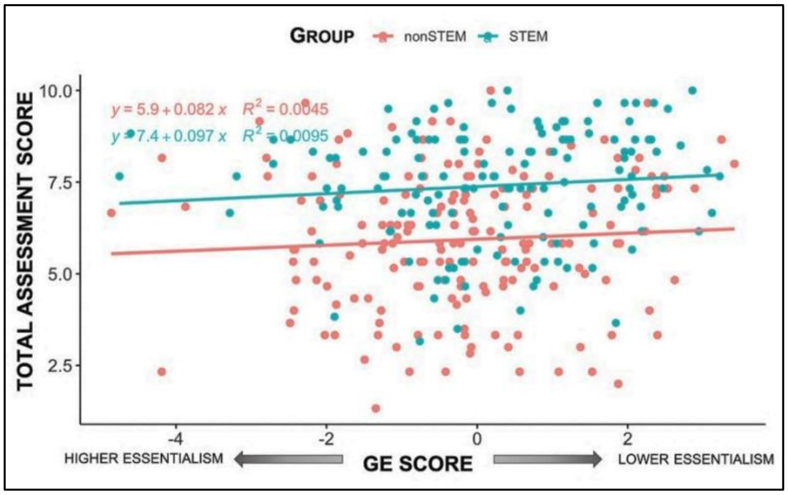


Figure 4a.
Relationship between assessment scores and GE scores, by participant group. Lower levels of essentialist perspectives correlate with higher assessment performance**.**

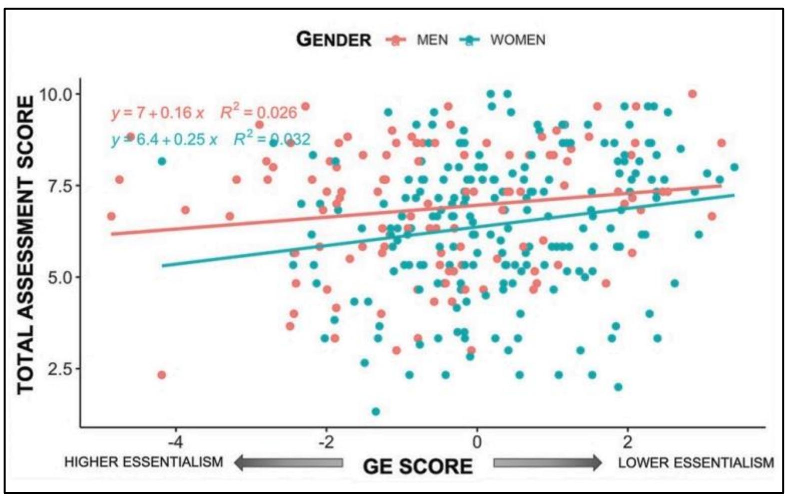


Figure 4b.
Relationship between s assessment scores and GE scores, by participant gender. The strength of the effect of GE score on assessment score differs by gender.

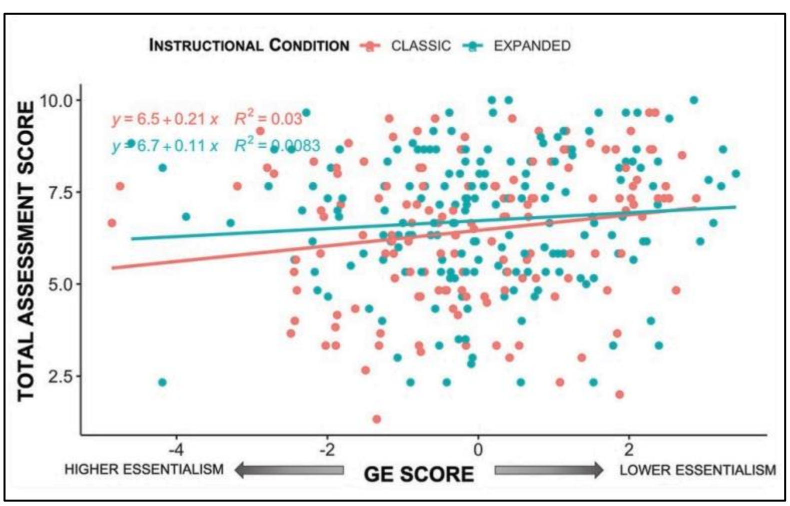


Figure 4c.
Relationship between assessment scores and GE scores, by treatment. The strength of the effect of GE score on assessment score differs by treatment.

Scores on the katydid question were positively correlated with total assessment scores ($r[319] = 0.2936$, $p<0.0001$), and a best subsets regression analysis with katydid score as the dependent variable and group, instructional condition, gender, and GE scores as independent variables revealed that group also explained most of the variation in katydid scores (Table 6, Figure 5a). Interaction effects of predictor variables for the katydid score were more difficult to interpret; as with total assessment scores, lower levels of essentialism correlated with higher katydid scores for women whereas for men, GE score was not related to katydid score (Figure 5b). However, gender interacted with group and instructional condition in such a way to suggest that this relationship holds for STEM women but not non-STEM women (Figure 6a) and is stronger for women who received the expanded instructional treatment than those who received the classic instructional treatment (Figure 6b).

Table 6. **Output for best model produced by subsets regression examining effects of participant group, gender, instructional condition, GE scores and interactions on katydid question scores.**

Explanatory Variable	Estimate	SE	t-value	p-value
Intercept	-0.25	0.08	-3.27	*
STEM	0.43	0.11	3.76	***
nonSTEM : GE	-0.14	0.10	-1.45	
STEM : GE	0.11	0.11	1.07	
nonSTEM : GE : Expanded	0.10	0.14	0.74	
STEM : GE : Expanded	-0.18	0.14	-1.28	
nonSTEM : GE : Classic : Women	0.18	0.14	1.28	
STEM : GE : Classic : Women	0.07	0.16	0.43	
nonSTEM : GE : Expanded : Women	0.01	0.14	0.10	
STEM : GE : Expanded : Women	0.40	0.14	2.89	**

R-squared	0.11
F-statistic	4.13(9,309)
p-value	4.97×10^{-05}

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$

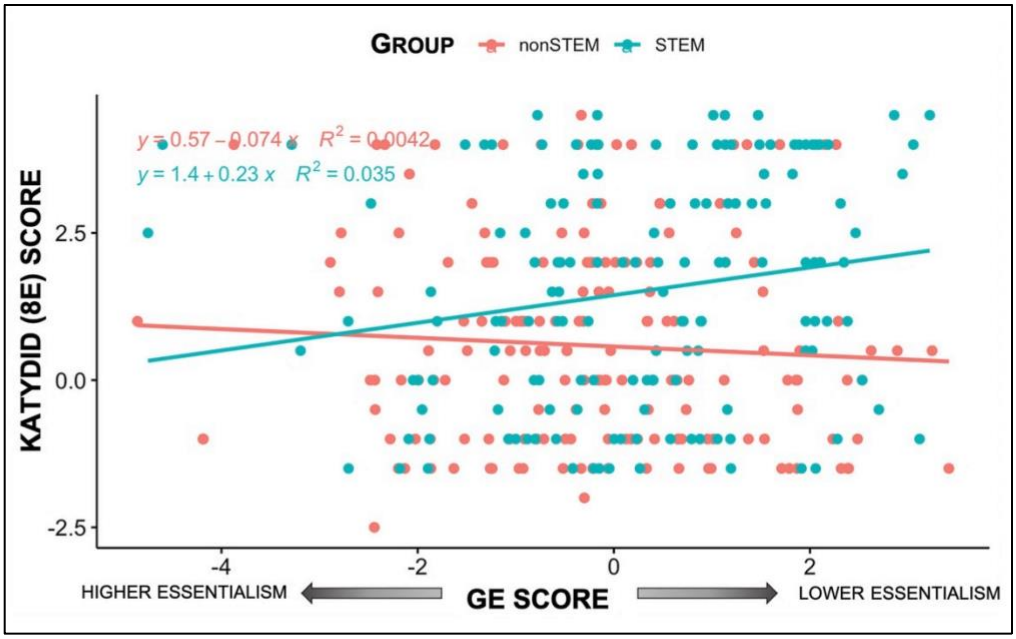


Figure 5a. **Relationship between katydid question scores and GE scores, by group.** Lower levels of essentialism correlated with higher katydid scores for STEM students but not non-STEM students.

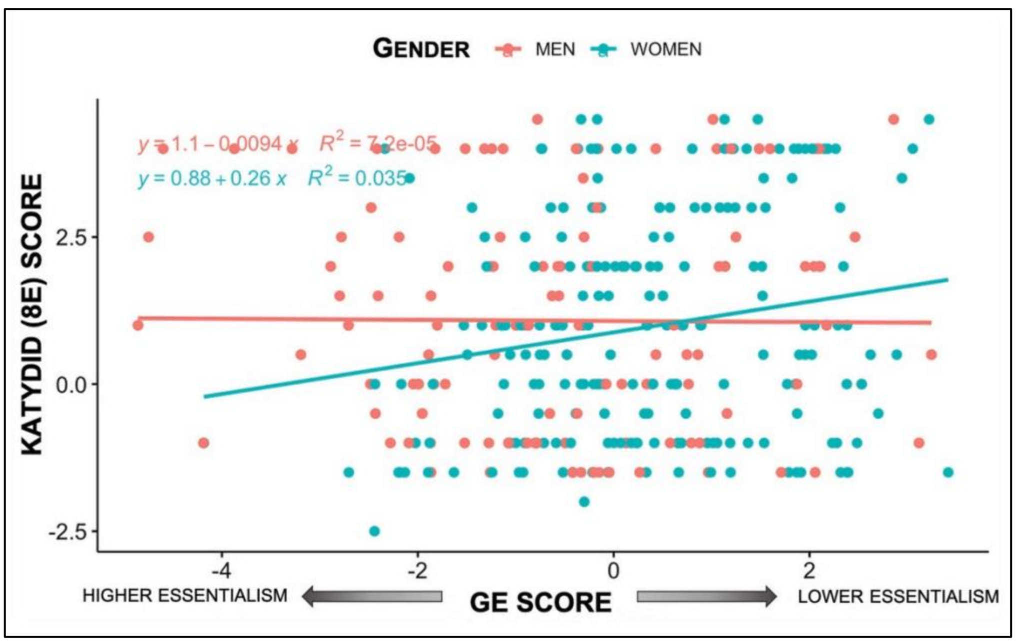


Figure 5b. **Relationship between katydid question scores and GE scores, by gender.** Lower levels of essentialism correlated with higher katydid scores for women but not men.

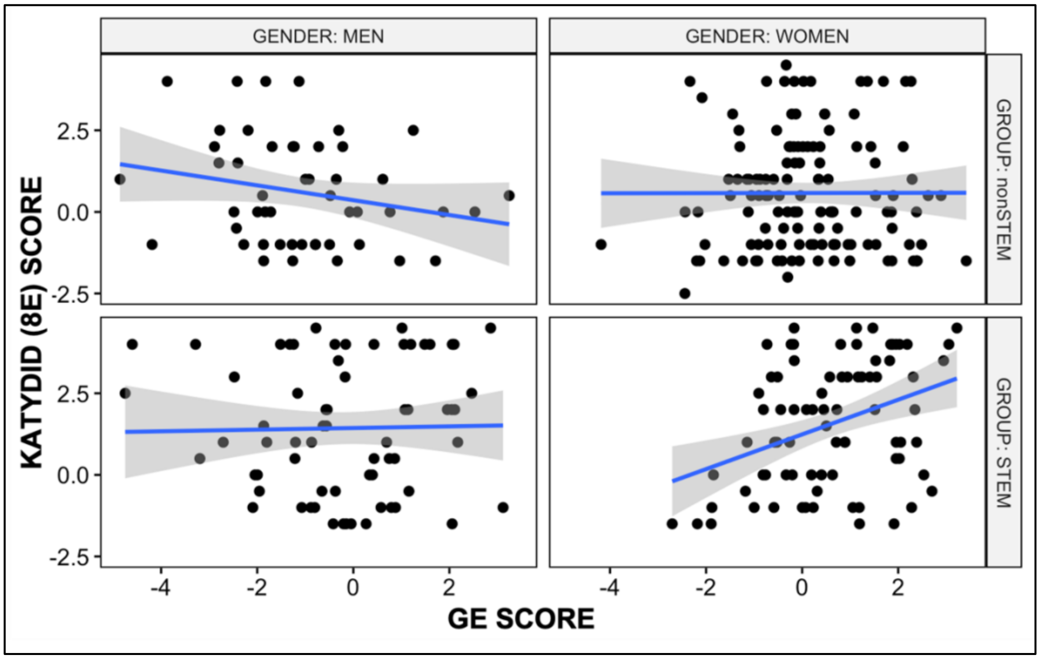


Figure 6a. **Interactions between participant gender and group affect the relationship between GE scores and katydid scores**.

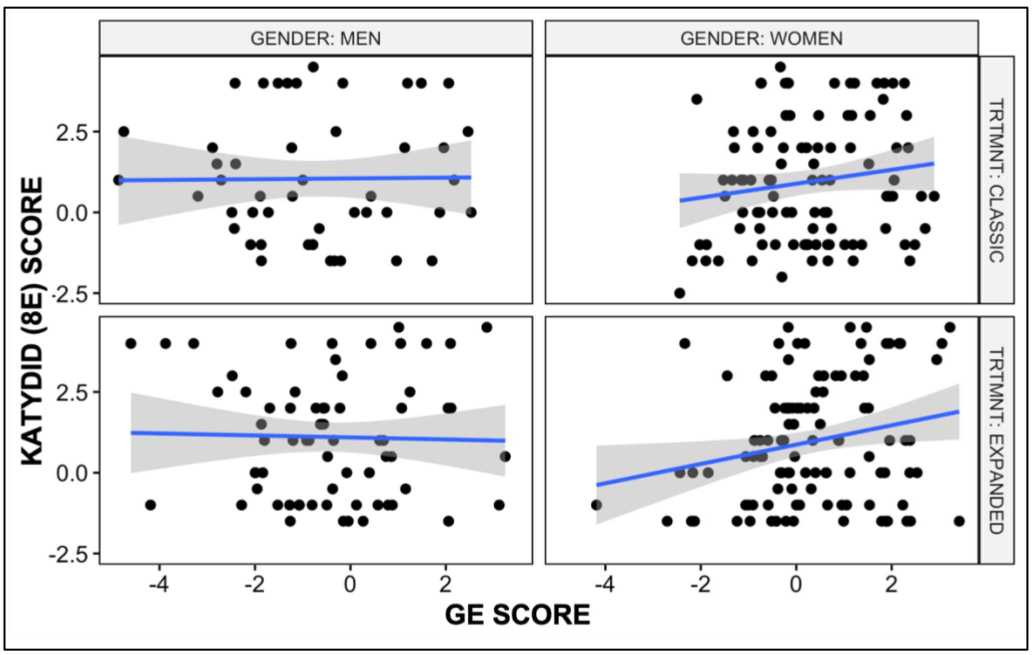


Figure 6b. **Interactions between participant gender and instructional condition affect the relationship between GE scores and katydid scores**

THE KATYDID QUESTION

Although most students (74%) chose the correct answer when asked to select the condition under which male [8a] and female [8c] katydids would exhibit choosy behavior, they often failed to provide written justifications for their selections that reflected a complete understanding of why their answers were true.

WHEN AND WHY ARE MALE KATYDIDS CHOOSY?

A high-quality answer to part 8b of the katydid question should indicate that male katydids are choosy under low-food conditions because spermatophore production is energetically expensive and males maximize their reproductive fitness by reserving these nutritious nuptial gifts for the best females. However, only 34% of students who correctly selected low-food environments as promoting male choosiness for part 8a of the katydid question explained that this occurred because males maximize their fitness by reserving energetically expensive spermatophores for the "best" females (Table 7). Rather, 49% of students who indicated that males were choosy in low-food conditions emphasized the cost of spermatophore production (without mentioning fitness), while 5% emphasized maximizing reproductive fitness (without mentioning the cost of the spermatophore). Justifications provided for male choosiness under low-food conditions differed significantly by participant group ($X^2[4,319]=33.19$, $p<0.0001$) and GE cluster ($X^2[8,319]=17.81$, $p=0.0227$); STEM students (46%) justified their selection for [8a] correctly more often than non-STEM students (21%), as did students in the LES cluster (44%) compared with those in the MEB (29%) and CTB clusters (28%).

Table 7. **Distribution of justification concept proportions (by grouping variable) provided by students who selected "low food" conditions as encouraging male choosiness in katydid reproductive interactions.**

Grouping Variable	[8a] Correct	[8b] Justification Concept				
		Cost +Fitness	Cost	Fitness	Choosy	Nonsensical
All Students	0.74	0.34	0.48	0.05	0.02	0.10
Group****						
STEM	0.82	**0.46**	0.50	0.02	0.01	0.02
non-STEM	0.68	0.21	0.49	0.08	0.03	**0.18**
Instructional Condition						
Classic	0.74	0.33	0.54	0.04	0.01	0.08
Expanded	0.75	0.34	0.46	0.06	0.02	0.11
Gender						
Men	0.75	0.26	0.52	0.02	0.02	0.08
Women	0.74	0.33	0.48	0.07	0.01	0.11
GE Cluster*						
CTB	0.74	0.28	0.46	0.04	0.06	0.15
MEB	0.73	0.29	0.53	0.05	0.01	0.12
LES	0.77	**0.44**	0.47	0.05	0.00	**0.03**

*$p < .05$. ****$p < 0.0001$

[a] Cost + Fitness indicates that a participant referenced fitness gains acquired by mating with best females when they compete for costly spermatophores.
[b] Cost indicates that a participant justified their choice by emphasizing the cost of spermatophore production to males.
[c] Fitness indicates that a participant justified their choice by emphasizing the need to increase fitness.
[d] Choosy indicates that a participant justified their selection by just restating that males are choosy.
[e] Nonsensical indicates that the meaning of a justification could not be determined or characterized.

Table 8. **Distribution of justification concept proportions (by grouping variable) provided by students who selected "high food" conditions as encouraging female choosiness in katydid reproductive interactions.**

Grouping Variable	[8c] Correct	[8d] Justification Concept				
		[a] Resources + Fitness	[b] Resources	[c] Fitness	[d] Choosy	[e] Nonsensical
All Students	0.74	0.17	0.64	0.05	0.01	0.13
Group*						
STEM	0.83	**0.23**	0.65	0.05	0.01	0.07
non-STEM	0.67	0.11	0.63	0.04	0.02	**0.20**
Instructional Condition						
Classic	0.77	0.13	0.67	0.04	0.02	0.13
Expanded	0.72	0.20	0.62	0.05	0.01	0.13
Gender						
Men	0.81	0.14	0.69	0.05	0.01	0.11
Women	0.71	0.19	0.61	0.04	0.01	0.15
GE Cluster*						
CTB	0.79	**0.09**	0.63	0.02	0.02	**0.24**
MEB	0.82	0.19	0.60	0.05	0.01	0.14
LES	0.74	0.19	0.71	0.05	0.01	0.03

*p < .05

[a] Resources + Fitness indicates that a participant referenced fitness gains acquired by mating with best males when released from competition for resources.
[b] Resources indicates that a participant justified their choice by emphasizing female release from competition for limited resources.
[c] Fitness indicates that a participant justified their choice by emphasizing the need to increase fitness.
[d] Choosy indicates that a participant justified their selection by just restating that females are choosy.
[e] Nonsensical indicates that the meaning of a justification could not be determined or characterized.

When and why are female katydids choosy?

A high-quality answer to part 8d of the katydid question should indicate that female katydids are choosy under high-food conditions because they are released from intrasexual competition for spermatophores and, as such, maximize their reproductive fitness by selecting the best male. However, only 17% of students who correctly selected [8c] high-food environments as promoting female choosiness explained that this was because [8d] females maximize their fitness by choosing the "best" male when not forced to compete with other females for nutritious spermatophores (Table 8). Rather, 64% of students who indicated that females were choosy in high-food environments emphasized release from resource competition (without mentioning fitness), while 5% emphasized maximizing reproductive fitness (without mentioning resource competition). Justifications for female choosiness under high-food conditions differed significantly by participant group (X^2[4,319]=13.24, p=0.0102) and GE cluster (X^2[8,319]=15.49, p=0.0455); non-STEM students (11%) were less likely to justify their selection for [8c] correctly than STEM students (23%) , as were students in the CTB cluster (9%) compared to the MEB (19%) and LES clusters (19%).

Content analysis of student short-answer responses

First-cycle codes for the open-ended student descriptions of katydid sex roles [8e] were developed using an approach that combined *Descriptive* and *In Vivo* coding methods (Saldaña, 2015), and iterative rounds of code-mapping and theming refined the qualitative data into three main categories: [1] *sexual selection concepts*, [2] *sex emphasis*, and [3] *problematic language* (Table 9). Two researchers coded the responses of 20 participants to evaluate inter-rater reliability using Cohen's kappa and rater agreement was high (*k* = 0.89). Sexual Selection Concepts (n = 9 codes): A high-quality answer to part 8e of the katydid question should indicate that katydid sex roles are [1] flexible, because [2] environmental conditions determine which sex is [3] choosier at any given time; these three concepts were considered to be *positive* concepts. Content analysis identified 6 additional concepts commonly found in the descriptions provided by students. Two of these were considered *negative* concepts and were either [4] nonsensical or referred to the [5] classic paradigm by emphasizing differences in appearance, reproductive behavior, etc. between the sexes. The remaining four concepts were considered to be *neutral*, as they conveyed accurate information that neither answered the question nor echoed the classic narrative. These included references to the male's [6] spermatophore, the drive to increase one's [7] reproductive fitness, the occurrence of [8] male (but not female) mate choice, and/or the occurrence of [9] female-female (but not male-male) competition for mating opportunities. In scoring written responses, participants earned one point for each positive concept and half a point for each neutral concept in their answers but lost one point for each negative concept included. Neutral concepts [8] and [9] are distinct from, but implicit to, positive concept [3]; accordingly, participants could earn between [-]2 to [+]4 points for the *concepts* included in their description of katydid sex roles.

Sex Emphasis (n = 4 codes): A high-quality description of katydid behaviors should place equal emphasis on the contributions of [1] both males *and* females in reproductive endeavors. Descriptions were coded as such if they explicitly described the behaviors of both male and female katydids without the use of value-laden or weighted terminology (e.g., *"…but the male does more of the work."*).

Table 9

Codes produced by content analysis of student descriptions of katydid sex roles for [8e] accompanied by representative example student responses.

Category	Code	Description	Example student response
Concept			
	FLEX	Flexible sex roles	*"Whether a male or female is choosy about reproducing depends on the amount of food in the environment."*
Positive	[a] CHOOSE	M & F mate choice	*"They both get to choose their mate."*
(+1)	ENVT	Role of environment	*"It depends on who is hungry."*
	NUPGIFT	Spermatophore offering	*"The male delivers his sperm to the female that has nutrition for the female to eat."*
Neutral	FITNESS	Optimize fitness	*"They both want the best option for more offspring."*
(+0.5)	[a] M_CHOOSY	Male mate choice	*"The male expends a lot of energy on sperm for the female, so they are selective when mating."*
	[a] F_CMPT	Female competition	*"There is female-female competition, so females really battle to get the best male to mate with."*
Negative	PARA	Classic paradigm	*"Males are the providers, and females are choosy and provide offspring."*
(-1)	NSNS	Nonsensical content	*"These sex roles play a crucial role in our understanding of katydid behavior as each is dependent on another."*
Sex Emphasis			
(+1)	EQ_EMPH	Emphasize M & F	*"Males are dominant when food sources are low, and females are dominant when food sources are high."*
(+0)	NO_EMPH	Neither sex emphasized	*"It is naturally selective because they depend on more than one factor."*
(-0.5)	M_EMPH	Emphasize male role	*"Males provide energy and nutrition to females, allowing them to survive and reproduce."*
(-0.5)	F_EMPH	Emphasize female role	*"Females hold all the power."*
Problematic Language			
		[Y] anthropomorphisms	*"The male is the dominant one and the female* ***conforms to his desires****."*
	ANTHRO	[N] anthropomorphisms	
		[Y] sex-stereotypes	*"The male seems to be* ***a provider*** *for the female."*
	STEREO	[N] sex-stereotypes	

Content analysis revealed that student descriptions often mentioned or emphasized the role of either [2] males or [3] females; there was a small number of responses in which the role of [4] neither sex was described. Answers coded describing the efforts of both males and females equally were awarded one point, while those describing neither sex received no points. Half a point was subtracted from the score when student descriptions emphasized the contribution or cost incurred by only one of the sexes. Consequently, participants could earn either [-]0.5, 0, or [+]1 point for the *emphasis* placed on the sexes within their description of katydid sex roles.

Problematic Language (n = 2 codes): A high-quality answer to part [e] of the katydid question should describe the interactions of katydids without using anthropomorphic and/or gender-stereotypic language; responses were coded for the presence/absence of problematic language. A response was considered to contain [1] anthropomorphic terminology if it described katydid sex roles using: words typically reserved for human social structures (e.g., *family, mom*), words reflecting human emotions (e.g., *jealous, happy*), and/or words associated with gender (e.g., *man, woman*). A response was considered to contain [2] gender-stereotypic terminology if it used language typically associated with stereotypic human gender roles; for example, describing male katydids as providers and females as caregivers. Responses were considered as containing both anthropomorphic *and* gender-stereotypic terminology if they included at least one of the criteria defined for anthropomorphic terminology and language associated with human gender roles. The use of problematic language did not factor into the score for the katydid question but was used when examining relationships between assessment scores, GE beliefs, and sexual selection concepts that emerged in written responses — providing a way to distinguish between the *content* of an answer and the way in which the content was *described* (i.e., it is possible for a student to describe all "positive" concepts in their response and still incorporate problematic language reflecting implicit biases within their responses).

STUDENT DESCRIPTIONS OF KATYDID SEX ROLES

Although 75% of STEM students selected both correct multiple-choice answers (indicating that low-resource environments promote male choosiness [8a], and high-resource environments promote female choosiness [8c]), fewer than half of these students (40%) described katydid sex roles as flexible in their written descriptions for part [8e] (Table 10). This conflict was also observed among non-STEM students, where 55% of students selected both correct multiple-choice answers, but fewer than one-quarter of these students (21%) described katydid sex roles as flexible. Chi-square analyses revealed that the descriptions of katydid sex roles provided by students differed significantly by group (X^2[5,319]=23.10, p=0.0003) and GE cluster (X^2[10,319]=24.11, p=0.0073), but not gender (X^2[5,319]=5.79, p=0.3274) or instructional condition (X^2[5,319]=4.13, p=0.5309). STEM students were more likely to describe katydid sex roles as flexible, whereas non-STEM students were more likely to reference the effect of environment or reiterate the classic paradigm. Similarly, participants from the LES cluster were more likely to describe katydid sex roles as flexible, while those from the MEB cluster often reiterated the classic paradigm and those from the CTB cluster emphasized the role of environmental conditions (Figure 7).

Table 10

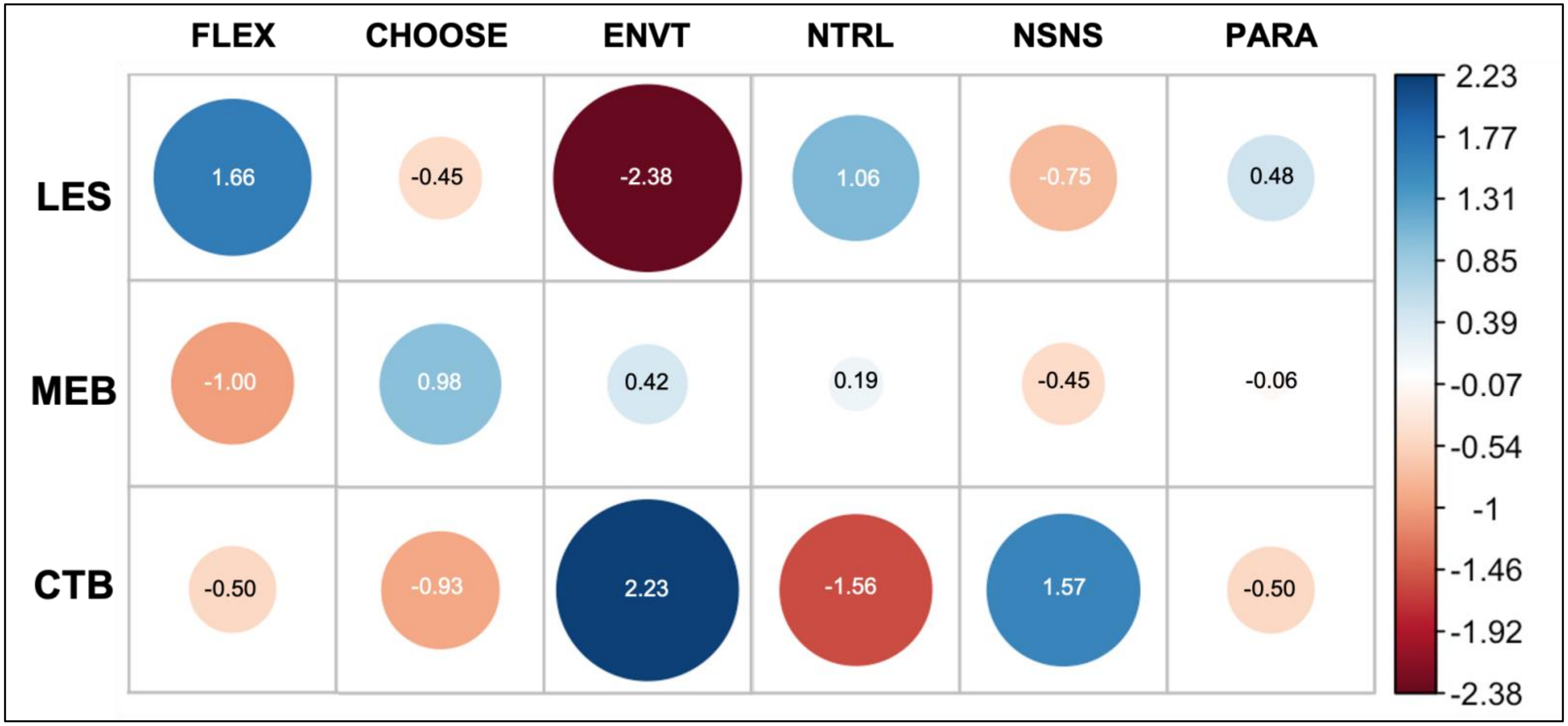
Proportions of participants who chose "low food" as encouraging male choosiness and "high food" as encouraging female choosiness, accompanied by the proportional breakdown of specific topics included in the descriptions of katydid sex roles provided by these students.

Grouping Variable	[8a + 8c] Correct	[8e] Katydid Sex Role Description Concept					
		[a] FLEX	[b] CHOOSE	[c] ENVT	[d] NTRL	[e] NSNS	[f] PARA
All Students	0.64	0.31	0.09	0.23	0.09	0.02	0.25
Group***							
STEM	0.75	0.40	0.10	0.18	0.09	0.01	0.23
non-STEM	0.55	0.21	0.08	0.28	0.08	0.04	0.27
Instructional Condition							
Classic	0.65	0.33	0.11	0.20	0.11	0.04	0.22
Expanded	0.64	0.30	0.08	0.26	0.07	0.01	0.27
Gender							
Men	0.70	0.38	0.06	0.24	0.10	0.03	0.18
Women	0.61	0.27	0.11	0.22	0.08	0.02	0.30
GE Cluster**							
CTB	0.65	0.30	0.02	0.39	0.05	0.02	0.23
MEB	0.63	0.27	0.11	0.24	0.08	0.02	0.27
LES	0.66	0.38	0.11	0.12	0.12	0.03	0.23

$*p < .05$. $**p < .01$. $***p < .001$

[a] FLEX indicates that a participant described katydid sex roles as flexible.
[b] CHOOSE indicates that a participant described katydid sex roles as one in which both males and females exhibit mate choice.
[c] ENVT indicates that a participant described katydid sex roles as being affected by environmental conditions.
[d] NTRL indicates that a participant described katydid sex roles only using neutral concepts (e.g. spermatophore, fitness).
[e] NSNS indicates that the meaning of a description could not be determined or characterized.
[f] PARA indicates that a participant reiterated the competitive male, choosy female paradigm when describing katydid sex roles.

Figure 7. **Correlation matrix displaying associations between GE clusters and katydid sex role description concepts.**



$X^2[10,319]=24.11$, $p=0.0073$

Note. Column labels refer to codes developed during content analysis of student responses for part [8e] of the katydid question, where FLEX = flexible sex roles, CHOOSE = male and female mate choice, ENVT = effect of environment, NTRL = neutral concepts, NSNS = nonsensical response, and PARA = classic paradigm. Row labels refer to GE clusters, where LES = liberal students who support egalitarian sex roles and endorse a social theory of gender, MEB = moderate students who support egalitarian sex roles and endorse a biological theory of gender, and CTB = conservative students who support traditional sex roles and endorse a biological theory of gender.

I anticipated that students who incorporated problematic language into their descriptions of katydid sex roles would demonstrate a more limited understanding of the theory and that this would be reflected in the content of their responses and their quantitative performance on the assessment. The use of problematic language in descriptions of katydid sex roles was most prevalent among students who reiterated the classic paradigm; almost all of these students (92.5%) used gender stereotypic language in their descriptions of katydid sex roles, and nearly 1/3 of them used both gender-stereotypic language and anthropomorphic terminology. In contrast, roughly 25% of students who described katydid sex roles as flexible used anthropomorphisms, and fewer than 10% used gender-stereotypic language or a combination of both.

Although language use was not directly incorporated into scoring of the katydid question, I found that individuals who used gender-stereotypic language in their written descriptions of katydid sex roles performed poorer on the katydid question and assessment overall. The mean katydid score for individuals who used gender-stereotypic language in their descriptions of katydid responses (μ =-0.50, *SD*=1.14) was significantly lower than that of individuals who did not use problematic language (μ =2.16, *SD*=1.38; $t[254]=16.32$, $p<0.0001$), and this trend was also observed when comparing the mean total assessment scores for individuals who used gender-stereotypic language (μ =6.344, *SD*=1.81) with the mean of individuals who did not (μ =6.831, *SD*=1.82; $t[254]=2.122$, $p=0.0348$). The use of anthropomorphic language was not related to total assessment score ($t[215]=0.1035$, $p=0.9177$); however, individuals who used anthropomorphisms earned significantly lower scores (μ =0.84, *SD*=2.07) on the katydid question than those who did not (μ =2.16, *SD*=1.38; $t[215]=5.527$, $p<0.0001$). Additionally, STEM students were significantly less likely to use either gender-stereotypic (*p*=0.0424) or anthropomorphic language (*p*=0.0409) in their descriptions of katydid sex roles than were non-STEM students. The use of gender-stereotypic language did not differ by instructional condition (*p*=0.8994), gender (*p*=0.8969), or GE cluster (X^2[2,285]=0.3603, *p*=0.8351); similarly, the use of anthropomorphic language did not differ by instructional condition (*p*=0.1919), gender (*p*=0.2840), or GE cluster (X^2[2,285]=0.08931, *p*=0.9563).

DISCUSSION

This multivariate statistical approach proved useful for obtaining a quantitative measure of gender essentialism from which distinct groups of individuals may be characterized by overlapping attitudes about sex roles, lay gender theory endorsement, and political ideology. I expected that participants with more essentialist attitudes would struggle with conceptualizing expanded sexual selection concepts, and my results suggest that strong essentialist perspectives may impede student understanding of concepts that highlight variation and flexibility as the norm. I predicted that the presentation of complex examples of sexual selection focused on expanded views — as opposed to classic views — would facilitate student understanding of the wide variety of ways in which sexual selection operates and found that some students benefit from this approach. I anticipated that misconceptions held by students about the theory might indicate limits in thinking about the targets of sexual selection (e.g., sexual selection acts on or is driven by males, but not females) but found that undergraduates often confuse sexual selection with natural selection and struggle with the concept of flexibility in reproductive behaviors. Finally, I predicted that students who used anthropomorphic and gender-stereotypic language when writing about sexual selection in non-human animals would demonstrate a more limited understanding of the theory, and analyses of assessment scores support this prediction.

GENDER ESSENTIALIST PERSPECTIVES IN UNDERGRADUATE STUDENTS

As was shown in earlier studies that investigated individual components of gender essentialism, I found that women are generally less essentialist than men and individuals holding liberal ideologies are less essentialist than those with conservative ideologies (Hoyt et al., 2018; Jost et al., 2003; Lee et al., 2011; Lye & Waldron, 1997). These data indicate that students who endorse a biological theory of gender support traditional sex roles if they identify as politically conservative — but support egalitarian sex roles if they identify as politically moderate. Similarly, students who support egalitarian sex roles endorse a biological theory of gender if they identify as politically moderate — but endorse a social theory of gender if they identify as politically liberal. These data also suggest that academic experience is related to the essentialist beliefs held by an individual. In this study population, STEM students were found to be less essentialist than non-STEM students and used problematic language in their written descriptions significantly less often. It may be that individuals who are less essentialist are more likely to major in a STEM field; however, because the STEM group was largely composed of 3rd and 4th year students while the non-STEM group was largely composed of 1st and 2nd year students, this difference may be more reflective of transformations in the process of "meaning making" (Magolda, 2009) that occur during an individual's personal development over the course of their college experience, rather than indicative of an effect of science interest or knowledge on implicit essentialist attitudes. Perhaps more importantly, these findings emphasize the multidimensional nature of gender essentialist beliefs and indicate that they are shaped by complex and interacting factors (e.g., one's gender, political ideology, academic experience, etc.) that should be considered from an intersectional perspective when investigating essentialist-related phenomena.

Conceptualizing Sexual Selection

Although participant group (i.e., STEM vs. non-STEM) was the greatest predictor of assessment scores, these data also indicate that lower levels of essentialism are positively related to increased performance on the assessment. Interaction effects revealed by the regression models indicate that overall performance on the assessment improved as a participant's degree of essentialism declined, and that this trend was strongest among women and students who received the classic instructional treatment. It is possible that, along with differing in respect to their essentialist beliefs, men and women also differ in how these beliefs impact their understanding of sexual-selection-related concepts. It may also be that less-essentialist individuals are more able to discern and overcome conflicts presented by an "external formula" (Magolda, 2009) — in this instance, the heteronormative narrative presented by the classic paradigm. The relationship between essentialist perspectives and understanding of sexual selection became more difficult to interpret when I shifted the analysis to the katydid question. Here, the relationship between lower levels of essentialism and higher scores on the question only held for STEM women and for women who received the expanded instructional treatment, suggesting that some women may conceptualize sexual selection better when presented with an expanded view.

Careful evaluation of how students answered each part of the katydid question revealed that many students, particularly those with more essentialist beliefs, are conflicted about the concept of behavioral flexibility in reproductive interactions. Potentially, this may be attributed to the deterministic principles scaffolding gender essentialism, which implicitly support firm boundaries and distinct, immutable groups (Rangel & Keller, 2011). Content analysis of written responses supported this notion, as the least essentialist students (i.e., the LES cluster) were most likely to emphasize the flexible nature of katydid sex roles, while the most essentialist students (i.e., the CTB cluster) were most likely to focus their responses on environmental factors. This may reflect important differences between core political ideologies — the only non-overlapping groups characterizing each cluster — as liberals have been shown to be more open to change and accepting of ambiguity, whereas conservatives are more resistant to change and crave certainty and closure (Furnham & Ribchester, 1995; Jost et al., 2003). Like the CTB cluster, moderately-essentialist students (i.e., the MEB cluster) resisted categorizing katydid sex roles as flexible; however, students in the MEB were the most inclined to emphasize that both male and female katydids exercised autonomy in mate preference and selection. These results are suggestive of an interesting interplay between essentialist beliefs and the approaches used by individuals to incorporate and justify novel information that conflicts with their internal ideology.

Study Limitations

Study participants were presented with a brief lesson on sexual selection, in an electronic format, and only once. There are obvious limitations to this format, and an in-person instructional format may better elucidate the effects of teaching a more inclusive and complex version of sexual selection through the lens of QCT. Additionally, although the study sample size was fairly large, the participant population in terms of race and gender was not as diverse as I hoped. For example, data interpretation was restricted to responses from students who identified as either men or women, as the small number of individuals ($n < 20$) who identified with an alternative gender category (e.g., non-binary) were ultimately removed from the dataset for meeting one of the exclusionary criteria. Finally, because the external factors that shape the trajectory of personal development can vary greatly by geography and socioeconomic status, it would be premature to claim that these findings hold true for all university students of all identity types in all locations. Rather, the interesting and significant relationships identified here between essentialist beliefs and conceptualization of sexual selection in students at *our* university highlight the need for a more rigorous and widespread study of these phenomena.

RECOMMENDATIONS

I argue that science educators should present a more nuanced and inclusive view of sexual selection rather than the classic paradigm, as this study found that [1] the presentation of complex and inclusive sexual selection topics can be accomplished without risking a loss of understanding in undergraduates, and [2] some students may better conceptualize the theory when presented with a more expanded view. Emphasizing variation in reproductive behaviors rather than a strictly classic interpretation of sexual selection that reinforces codified sex roles may help to interrupt deterministic thinking that appears to impede student perceptions of organisms and their interactions as plastic, flexible, and variable. The framework of QCT offers an approach for facilitating this by raising awareness of biased, value-laden, and heteronormative practices within academia and endorsing a more fluid concept of gender and sexuality that enriches our understanding of diversity (Sumara & Davis, 1999). However, as essentialist attitudes are well-formed by the time students engage in higher learning, my characterization of three distinct categories of essentialist perspectives suggests that this might require different pedagogical techniques for different types of students. In order to have a meaningful and lasting effect, educators should incorporate examples like that of flexible katydid sex roles into their curriculum, create spaces to discuss the influence of gender essentialist perspectives on interpretations of non-human animal behavior, and encourage students to consider their own biases and those of the scientists who created the knowledge being presented. Literacy in socio-scientific issues (e.g., essentialism and its scientific and cultural ramifications) may help to reduce prejudicial thinking and *can* be achieved using data-driven approaches (e.g., Donovan et al., 2020). Future studies might examine potential pedagogical interventions or the impact of sustained curricular integration of inclusionary examples in which educators highlight variation among individuals rather than, for example, differences between boys and girls. In fact, a true paradigm shift away from the exclusionary, androcentric and heteronormative narrative may only occur if early science educators incorporate a QCT framework into their practice that highlights the history of science and emphasizes phenomenological themes of sex and genders as fluid concepts shaped by human history and cultures.

REFERENCES

Ah-King, M. (2013). On anisogamy and the evolution of "sex roles." In *Trends in Ecology and Evolution*. https://doi.org/10.1016/j.tree.2012.04.004

Ah-King, M. (2018). Queer Nature. Towards a Non-normative View on Biological Diversity. *Das Geschlecht in der Biologie: Aufforderung zu Einem Perspektivwechsel*, *12*, 115-132

Ah-King, M., & Ahnesjö, I. (2013). The "Sex Role" Concept: An Overview and Evaluation. Evolutionary Biology, 40, 461–470. https://doi.org/10.1007/s11692-013-9226-7

Ah-King, M., & Nylin, S. (2010). Sex in an Evolutionary Perspective: Just Another Reaction Norm. Evolutionary Biology. https://doi.org/10.1007/s11692-010-9101-8

Ahnesjö, I., Brealey, J., Günter, K., Martinossi-Allibert, I., Morinay, J., Siljestam, M., Stångberg, J., & Vasconcelos, P. (2020). Considering Gender-Biased Assumptions in Evolutionary Biology. Evolutionary Biology, 47(1). https://doi.org/10.1007/s11692-020-09492-z

Altmann, J. (2009). Observational Study of Behavior : Sampling Methods Author (s): Jeanne Altmann Published by : BRILL Stable URL : http://www.jstor.org/stable/4533591. Behaviour, 49(3), 227–267. https://doi.org/10.1080/14794802.2011.585831

Amato, P., & Booth, A. (1995). Changes in gender role attitudes and perceived marital quality. American Sociological Review, 60 (1), 58-66.

Amundsen, T. (2000). Why are female birds ornamented? Trends in Ecology and Evolution, 15(4), 149–155. https://doi.org/10.1016/S0169-5347(99)01800-5

Anderson, D., Fisher, K., & Norman, G. (2002). Development and evaluation of the conceptual inventory of natural selection. Journal of Research in Science Teaching, 39(10), 952–978. https://doi.org/10.1002/tea.10053

Arnqvist, G. (1989). Multiple mating in a water strider: mutual benefits or intersexual conflict?. *Animal Behaviour*, *38*(5), 749-756.

Arnqvist, G., & Nilsson, T. (2000). The evolution of polyandry: Multiple mating and female fitness in insects. *Animal Behaviour*, *60*(2), 145–164.

Bartko, J. (1978). On various intraclass correlation reliability coefficients. Psychological Bulletin, 83(5), 762–765. https://doi.org/10.1037/0033-2909.85.1.135

Bateman, A. (1948). Intra-sexual selection in Drosophila. Heredity, 2, 349–368. https://doi.org/10.1007/BF01407191

Bianchi, S., Lesnard, L., Nazio, T., & Raley, S. (2014). Gender and time allocation of cohabiting and married women and men in France, Italy, and the United States. Demographic Research, 31(1), 183–216. https://doi.org/10.4054/DemRes.2014.31.8

Bianchi, S., & Milkie, M. (2010). Work and family research in the first decade of the 21st century. Journal of Marriage and Family, 72(3), 705–725. https://doi.org/10.1111/j.1741-3737.2010.00726.x

Blackwell, A. L. B. (1875). *The sexes throughout nature.* New York: GP Putnam.

Bowen, G. M., & Roth, W. M. (2002). Why students may not learn to interpret scientific inscriptions. *Research in Science Education*, *32*(3), 303-327.

Broadway, F. (2011). Queer (v.) queer (v.): Biology as curriculum, pedagogy, and being albeit queer (v.). Cultural Studies of Science Education, 6(2), 293–304. https://doi.org/10.1007/s11422-011-9325-7

Brown, C., & Stone, E. (2016). Gender stereotypes and discrimination. How sexism impacts development. Advances in Child Development and Behavior, 50, 105-133. https://doi.org/10.1016/bs.acdb.2015.11.001

Brugeilles, C., & Cromer, S. (2009). Analysing gender representations in school textbooks. Paris : UMR CEPED

Bull, C. M. (2000). Monogamy in lizards. *Behavioural Processes*, *51*(1–3), 7–20. https://doi.org/10.1016/S0376-6357(00)00115-7

Buskirk, R. E., Frohlich, C., & Ross, K. G. (1984). The natural selection of sexual cannibalism. *The American Naturalist*, *123*(5), 612-625.

Carney, R. N., & Levin, J. R. (2002). Pictorial illustrations Still improve students' learning from text. *Educational Psychology Review*, *14*(1), 5–26. https://doi.org/10.1023/A:1013176309260

Carter, S., Devries, A., & Getz, L. (1995). Physiological substrates of mammalian monogamy: The prairie vole model. Neuroscience and Biobehavioral Reviews, 19(2), 303–314. https://doi.org/10.1016/0149-7634(94)00070-H

Clutton-Brock, T. (2007). Sexual selection in males and females. Science, 318(5858), 1882-1885.

Clutton-Brock, T. (2017). Reproductive competition and sexual selection. Philosophical Transactions of the Royal Society B: Biological Sciences, 372(1729), 20160310.

Cohen, G., Aronson, J., & Steele, C. (2000). When beliefs yield to evidence: Reducing biased evaluation by affirming the self. *Personality and social psychology bulletin*, *26*(9), 1151-1164.

Cohen, J. (1960). A coefficient of agreement for nominal scales. *Educational and Psychological Measurement*, *XX*(1), 37–46.

Coleman, J., & Hong, Y. (2008). Beyond nature and nurture: The influence of lay gender theories on self-stereotyping. Self and Identity, 7(1), 34–53. https://doi.org/10.1080/15298860600980185

Cronin, H. (1993). The ant and the peacock: Altruism and sexual selection from Darwin to today. Cambridge University Press.

Dacey, M. (2017). Anthropomorphism as cognitive bias. Philosophy of Science, 84(5), 1152–1164. https://doi.org/10.1086/694039

Damschen, E. I., Rosenfeld, K. M., Wyer, M., Murphy-Medley, D., Wentworth, T. R., & Haddad, N. M. (2005). Visibility matters: Increasing knowledge of women's contributions to ecology. *Frontiers in Ecology and the Environment*, *3*(4), 212–219. https://doi.org/10.1890/1540-9295(2005)003[0212:VMIKOW]2.0.CO;2

Darwin, C. (1871). The descent of man, and selection in relation to sex. London: John Murray.

David, D., Dhonnchadha, B., Jolliet, P., Hascoët, M., & Bourin, M. (2001). Are there gender differences in the temperature profile of mice after acute antidepressant administration and exposure to two animal models of depression? Behavioural Brain Research, 119(2), 203–211. https://doi.org/10.1016/S0166-4328(00)00351-X

Davies, J. (2010). Anthropomorphism in science. EMBO Reports, 11(10), 721. https://doi.org/10.1038/embor.2010.143

Davies, P. G., & Spencer, S. J. (2005). *The Gender-Gap Artifact: Women's Underperformance in Quantitative Domains Through the Lens of Stereotype Threat*. Cambridge University Press.

Dewsbury, D. A. (2005). The Darwin-Bateman paradigm in historical context. *Integrative and Comparative Biology*, *45*(5), 831-837.

Diekman, A., & Eagly, A. (2000). Stereotypes as dynamic constructs: Women and men of the past, present, and future. Personality and Social Psychology Bulletin, 26(10), 1171–1188. https://doi.org/10.1177/0146167200262001

Donovan, B., Weindling, M., Salazar, B., Duncan, A., Stuhlsatz, M., & Keck, P. (2020). Genomics literacy matters: Supporting the development of genomics literacy through genetics education could reduce the prevalence of genetic essentialism. Journal of Research in Science Teaching, October, 1–31. https://doi.org/10.1002/tea.21670

Dougherty, L., Burdfield-Steel, E., & Shuker, D. (2013). Sexual stereotypes: The case of sexual cannibalism. Animal Behaviour, 85(2), 313–322. https://doi.org/10.1016/j.anbehav.2012.12.008

Dunn, P., & Lifjeld, J. (1994). Can extra-pair copulations be used to predict extra-pair paternity in birds? In Animal Behaviour, 47(4), 983-985. https://doi.org/10.1006/anbe.1994.1132

Eidlin, F. (1981). Western Political Theory in the Face of the Future. John Dunn (Ed) New York: Cambridge University Press, 1979, pp. viii, 120. Canadian Journal of Political Science, 14(1), 183–184. https://doi.org/10.1017/s0008423900035678

Emlen, S., & Oring, L. (2007). Evolution of Mating Systems. 197(4300), 215–223.

Epley, N., Waytz, A., & Cacioppo, J. (2007). On Seeing Human: A Three-Factor Theory of Anthropomorphism. Psychological Review, 114(4), 864–886. https://doi.org/10.1037/0033-295X.114.4.864

Ewald, H. (2016). Who are we talking about anyway?: Anthropomorphism and its implications in wildlife films and biology textbooks.

Fausto-Sterling, A. (1997). Beyond difference: A biologist's perspective. *Journal of Social Issues*, *53*(2), 233-258.

Fausto-Sterling, A. (2019). Gender/sex, sexual orientation, and identity are in the body: How did they get there? Journal of Sex Research, 56(4–5), 529–555. https://doi.org/10.1080/00224499.2019.1581883

Ferguson, J., Collison, D., Power, D., & Stevenson, L. (2006). Accounting textbooks: Exploring the production of a cultural and political artifact. *Accounting Education*, *15*(3), 243–260. https://doi.org/10.1080/09639280600850679

Flerx, V., Fidler, D., & Rogers, R. (1976). Sex role stereotypes: Developmental aspects and early intervention. Child Development, 47(4), 998–1007.

Ford, M. (2008). Disciplinary authority and accountability in scientific practice and learning. *Science Education*, *92*(3), 404–423. https://doi.org/10.1002/sce.20263

Furnham, A., & Ribchester, T. (1995). Tolerance of ambiguity: A review of the concept, its measurement and applications. Current Psychology, 14(3), 179–199. https://doi.org/10.1007/BF02686907

Fuselier, L., Jackson, K., & Stoiko, R. (2016). Social and rational: the presentation of nature of science and the uptake of change in evolution textbooks. *Science education, 100*(2), 239-265.

Fuselier, L., Eason, P., Jackson, K., & Spaulding, S. (2018). Images of objective knowledge construction in sexual selection chapters of evolution textbooks. *Science & Education, 27*(5): 479-499.

Gadagkar, R. (2003). Is the peacock merely beautiful or also honest? Current Science, 85(7), 1012–1020.

Gamble, E. B. (1893). *The evolution of woman: an inquiry into the dogma of her inferiority to man.* New York: GP Putnam's Sons.

Gedro, J., & Mizzi, R. (2014). Feminist theory and queer theory: Implications for HRD research and practice. Advances in Developing Human Resources, 16(4), 445–456. https://doi.org/10.1177/1523422314543820

Good, J. J., Woodzicka, J. A., & Wingfield, L. C. (2010). The effects of gender stereotypic and counter-stereotypic textbook images on science performance. *The Journal of social psychology*, *150*(2), 132-147.

Goulden, M., Mason, M., & Frasch, K. (2011). Keeping women in the science pipeline. Annals of the American Academy of Political and Social Science, 638(1), 141–162. https://doi.org/10.1177/0002716211416925

Gowaty, P. A. (1997). Sexual dialectics, sexual selection, and variation in reproductive behavior. In *Feminism and evolutionary biology* (pp. 351-384). Springer, Boston, MA.

Gowaty, P. (2017). Biological essentialism, gender, true belief, confirmation biases, and skepticism. APA Handbook of the Psychology of Women: History, Theory, and Battlegrounds (Vol. 1)., 145–164. https://doi.org/10.1037/0000059-008

Gowaty, P. (2018). On being and becoming female and male. *Gender, Sex, and Sexualities: Psychological Perspectives*, 77.

Green, K.K., & Madjidian, J. (2011). Active males, reactive females: Stereotypic sex roles in sexual conflict research? Animal Behaviour, 81(5), 901–907. https://doi.org/10.1016/j.anbehav.2011.01.033

Gullicks, K. A., Pearson, J. C., Child, J. T., & Schwab, C. R. (2005). Diversity and power in public speaking textbooks. *Communication Quarterly*, *53*(2), 247–258. https://doi.org/10.1080/01463370500089870

Hallgren, K. A. (2012). Computing Inter-Rater Reliability for Observational Data: An Overview and Tutorial. *Tutorials in Quantitative Methods for Psychology*, *8*(1), 23–34.

Harrison, M. A., & Hall, A. E. (2010). Anthropomorphism, empathy, and perceived communicative ability vary with phylogenetic relatedness to humans. *Journal of Social, Evolutionary, and Cultural Psychology*, *4*(1), 34–48. https://doi.org/10.1037/h0099303

Haslam, N., Rothschild, L., & Ernst, D. (2002). Are essentialist beliefs associated with prejudice? British Journal of Social Psychology, 41(1), 87–100. https://doi.org/10.1348/014466602165072

Heyman, G. & Giles, J. (2006). Gender and psychological essentialism. *Enfance, 58*(3), 293-310.

Hogben, M., & Waterman, C. (1997). Are all of your students represented in their textbooks? A content analysis of coverage of diversity issues in introductory psychology textbooks. Teaching of Psychology, 24(2), 95–100. https://doi.org/10.1207/s15328023top2402_3

Hoyt, C., Forsyth, R., & Burnette, J. (2018). Social dominance orientation moderates the effectiveness of mindset messages. British Journal of Social Psychology, 57(2), 448–460. https://doi.org/10.1111/bjso.12238

Hubbard, R. (1988). Science, Facts, and Feminism. *Hypa*, *3*(1), 5–17.

Inzlicht, M. & Benn-Zeev, T. (2000). A threatening intellectual environment: Why females are susceptible to experiencing problem-solving deficits in the presence of males. *Psychological Science, 11*(5): 365-371.

Jackson, J.K. (2014). Science studies perspectives on animal behavior research: Toward a deeper understanding of gendered impacts. Hypatia, 29(4), 738-754.

Jost, J., Glaser, J., Kruglanski, A., & Sulloway, F. (2003). Political conservatism as motivated social cognition. Psychological Bulletin, 129(3), 339–375. https://doi.org/10.1037/0033-2909.129.3.339

Keller, J. (2005). In genes we trust: The biological component of psychological essentialism and its relationship to mechanisms of motivated social cognition. *Journal of Personality and Social Psychology*, *88*(4), 686–702. https://doi.org/10.1037/0022-3514.88.4.686

Koch, J. (2003). Gender in the classroom. *Handbook of psychology*: 259-281.

Klysing, A. (2020). Exposure to scientific explanations for gender differences influences individuals' personal theories of gender and their evaluations of a discriminatory situation. Sex Roles, 82(5–6), 253–265. https://doi.org/10.1007/s11199-019-01060-w

Kraaijeveld, K., Kraaijeveld-Smit, F., & Komdeur, J. (2007). The evolution of mutual ornamentation. Animal Behaviour, 74(4), 657–677. https://doi.org/10.1016/j.anbehav.2006.12.027

Kray, L., Howland, L., Russell, A., & Jackman, L. (2017). The effects of implicit gender role theories on gender system justification: Fixed beliefs strengthen masculinity to preserve the status quo. Journal of Personality and Social Psychology, 112(1), 98–115. https://doi.org/10.1037/pspp0000124

Kress, G., & Van Leeuwen, T. (1996) Reading images: the grammar of visual design. London: Psychology Press.

Kuchynka, S., Salomon, K., Bosson, J., El-Hout, M., Kiebel, E., Cooperman, C., & Toomey, R. (2018). Hostile and benevolent sexism and college women's STEM outcomes.

Psychology of Women Quarterly, 42(1), 72–87. https://doi.org/10.1177/0361684317741889

Lawrence, S. C., & Bendixen, K. (1992). His and Hers : Male and Female Anatomy in Anatomy Texts for His and Hers : Male and Female Anatomy in Anatomy Texts for U. S. Medical Students, 1890 – 1989. *Social Science and Medicine*, *35*(7), 925–934.

Larsen, K., & Long, E. (1988). Attitudes toward sex-roles: Traditional or egalitarian? Sex Roles, 19(1–2), 1–12. https://doi.org/10.1007/BF00292459

Lee, I., Pratto, F., & Johnson, B. (2011). Intergroup consensus/disagreement in support of group-based hierarchy: an examination of socio-structural and psycho-cultural factors. Psychological Bulletin, 137(6), 1029–1064. https://doi.org/10.1037/a0025410.Intergroup

Libell, M. (2014). Seeing Animals. Anthropomorphism between Fact and Function. *EXPLORING THE ANIMAL TURN*, 141.

Longino, H. (2002). *The social dimensions of scientific knowledge*. Accessed at https://plato.stanford.edu/entries/scientific-knowledge-social/

Lueptow, L., Garovich, L., & Lueptow, M. (1995). The persistence of gender stereotypes in the face of changing sex roles: Evidence contrary to the sociocultural model. Ethology and Sociobiology, 16(6), 509–530. https://doi.org/10.1016/0162-3095(95)00072-0

Lye, D., & Waldron, I. (1997). Attitudes toward cohabitation, family, and gender roles: Relationships to values and political ideology. Sociological Perspectives, 40(2), 199–225. https://doi.org/10.2307/1389522

Magolda, M. (2009). The activity of meaning making: A holistic perspective on college student development. Journal of College Student Development, 50(6), 621–638. https://doi.org/10.1353/csd.0.0106

Marke, S., & Gottfries, I. (1979). Sex-role scales 1 and 2. *Women and Women's Issues, 10*: 223-225.

Martin, C., & Parker, S. (1995). Folk theories about sex and race differences. Personality and Social Psychology Bulletin, 21(1), 45–57.

Martin, E. (1991). The Egg and the sperm : How science has constructed a romance based on stereotypical male-female roles. Signs: Journal of Women in Culture and Society, 16(3), 485-501.

McNeish, D. (2018). Thanks coefficient alpha, we'll take it from here. Psychological Methods, 23(3), 412–433. https://doi.org/10.1037/met0000144

Metoyer, A. B., & Rust, R. (2011). The egg, sperm, and beyond: Gendered assumptions in gynecology textbooks. *Women's Studies*, *40*(2), 177–205. https://doi.org/10.1080/00497878.2011.537986

Moore, L. J., & Clarke, A. E. (1995). Clitoral Conventions and Transgressions : Graphic Representations in Anatomy Texts, c1900-1991. *Feminist Studies*, *21*(2), 255–301.

Morris, P., Fidler, M., & Costall, A. (2000). Beyond Anecdotes: An Empirical Study of "Anthropomorphism." *Society and Animals*, *8*(2), 151–165. https://doi.org/10.1163/156853000511050

Morton, T., Postmes, T., Haslam, S., & Hornsey, M. (2009). Theorizing gender in the face of social change: Is there anything essential about essentialism? Journal of Personality and Social Psychology, 96(3), 653–664. https://doi.org/10.1037/a0012966

Moss-Racusin, C. A., Dovidio, J. F., Brescoll, V. L., Graham, M. J., & Handelsman, J. (2012). Science faculty's subtle gender biases favor male students. *Proceedings of the National*

Academy of Sciences of the United States of America, *109*(41), 16474–16479. https://doi.org/10.1073/pnas.1211286109

Moss-Racusin, C. A., Molenda, A. K., & Cramer, C. R. (2015). Can Evidence Impact Attitudes? Public Reactions to Evidence of Gender Bias in STEM Fields. *Psychology of Women Quarterly*, *39*(2), 194–209. https://doi.org/10.1177/0361684314565777

Myers, G. (1988). Every Picture Tells a Story : Illustrations in E . O . Wilson ' s Sociobiology Author (s): Greg Myers Source : Human Studies , Vol . 11 , No . 2 / 3 , Representation in Scientific Practice. *Human Studies*, *11*(2), 235–269.

National Research Council. (2010). Gender differences at critical transitions in the careers of science, engineering, and mathematics faculty. National Academies Press.

Niaz, M., & Maza, A. (2011). Nature of science in general chemistry textbooks, pp. 1-37. Springer, Dordrecht.

Parker, R., Larkin, T., & Cockburn, J. (2017). A visual analysis of gender bias in contemporary anatomy textbooks. *Social Science and Medicine*, *180*, 106–113. https://doi.org/10.1016/j.socscimed.2017.03.032

Pauwels, L. (2008). Visual Literacy and Visual Culture: Reflections on Developing More Varied and Explicit Visual Competencies. *The Open Communication Journal*, *2*(1), 79–85. https://doi.org/10.2174/1874916x00802010079

Peterson, S. B., & Kroner, T. (1992). Gender Biases in Textbooks for Introductory Psychology and Human Development. *Psychology of Women Quarterly*, *16*(1), 17–36. https://doi.org/10.1111/j.1471-6402.1992.tb00237.x

Porreca, K. L. (1984). Sexism in Current ESL Textbooks. *TESOL Quarterly*, *18*(4), 705. https://doi.org/10.2307/3586584

Prior, P., & Bilbro, R. (2012). Academic enculturation: Developing literate practices and disciplinary identities. *University Writing: Selves and Texts in Academic Societies*, 19–31. https://doi.org/10.1163/9781780523873_003

Prosser, J., & Schwartz, D. (1998). Photographs within the sociological research process. *Image-Based Research: A Sourcebook for Qualitative Researchers*, 101–115.

Rangel, U., & Keller, J. (2011). Essentialism goes social: Belief in social determinism as a component of psychological essentialism. Journal of Personality and Social Psychology, 100(6), 1056–1078. https://doi.org/10.1037/a0022401

Reis, H. & Wright S. (1982) Knowledge of sex-role stereotypes in children aged 3 to 5. Sex Roles, 8(10), 1049-1056.

Ridgeway, C. (2009). Framed before we know it: How gender shapes social relations. Gender & society, 23(2), 145-160.

Roughgarden, J. (2012). The social selection alternative to sexual selection. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *367*(1600), 2294–2303. https://doi.org/10.1098/rstb.2011.0282

Ross, S., & Jackson, J. (1991). Teachers' expectations for Black males' and Black females' academic achievement. *Personality and Social Psychology Bulletin, 17*(1): 78-82.

Rowell, B. (1967). A quantitative comparison of the behaviour of a wild and caged baboon group. Animal Behaviour, 15, 499–509.

Sadker, D., & Zittleman, K. (2007). Gender bias: From colonial America to today's classrooms. *Multicultural education: Issues and perspectives*, 135-169.

Saldaña, J. (2015). *The coding manual for qualitative researchers*. Sage.

Sánchez, J., & Belmar, A. (2006). Pedro Gutiérrez Bueno's textbooks: Audiences, teaching practices and chemical revolution. Science and Education, 15(7–8), 693–712. https://doi.org/10.1007/s11191-004-8429-9

Schuster, P., & Sigmund, K. (1981). Coyness, philandering and stable strategies. *Animal Behaviour*, *29*(1), 186-192.

Schwartz, D. (1989). Visual ethnography: Using photography in qualitative research. *Qualitative sociology*, *12*(2), 119-154.

Simmons, L. (1995). Relative parental expenditure, potential reproductive rates, and the control of sexual selection in katydids. The American Naturalist, 145(5), 797-808.

Simon, R., Wagner, A., & Killion, B. (2017). Gender and choosing a STEM major in college: Femininity, masculinity, chilly climate, and occupational values. Journal of Research in Science Teaching, 54(3), 299–323. https://doi.org/10.1002/tea.21345

Sleeter, C. & Grant, C. (1985). Race, class, and gender in an urban school, a case study. *Urban Education*, *20*(1): 37-60.

Snyder, B. F., & Gowaty, P. A. (2007). A reappraisal of Bateman's classic study of intrasexual selection. *Evolution*, *61*(11), 2457–2468. https://doi.org/10.1111/j.1558-5646.2007.00212.x

Stamps, J. (1997). The role of females in extrapair copulations in socially monogamous territorial animals. In Feminism and evolutionary biology (pp. 294-319). Springer, Boston, MA.

Steele, C. M. (1997). A Threat in the Air: How Stereotypes Shape Intellectual Identity and Performance. *American Psychologist*, *52*(6), 613–629. https://doi.org/10.1037/0003-066X.52.6.613

Stromquist, N., Lee, M., & Brock-Utne, B. (1998). The explicit and the hidden school curriculum. *Women in the third world: An encyclopedia of contemporary issues*, 397-407.

Sumara, D., & Davis, B. (1999). Interrupting heteronormativity: Toward a queer curriculum theory. Curriculum Inquiry, 29(2), 191–208. https://doi.org/10.1111/0362-6784.00121

Sutherland, W. J. (1985). Chance can produce a sex difference in variance in mating success and explain Bateman's data. *Animal Behaviour*, *33*(4), 1349–1352. https://doi.org/10.1016/S0003-3472(85)80197-4

Tang-Martínez, Z. (2012). Repetition of Bateman challenges the paradigm. *PNAS*, *109*(29), 11476-11477. https://doi.org/10.1073/pnas.1209394109

Tang-Martínez, Z. (2016). Rethinking Bateman's principles: challenging persistent myths of sexually reluctant females and promiscuous males. The Journal of Sex Research, 53(4-5), 532-559.

Thorne, B. (1993). *Gender play: Girls and boys in school.* Rutgers University Press.

Thornhill, R., & Thornhill, N. W. (1983). Human rape: An evolutionary analysis. *Ethology and Sociobiology*, *4*(3), 137-173.

Trivers, R. (1972). Parental investment and sexual selection. In 'Sexual Selection and the Descent of Man'.(Ed. B. Campbell.) pp. 136–179. Aldinc: Chicago, 13(2).

Unger, R. (1979). Toward a redefinition of sex and gender. American Psychologist, 34(11), 1085–1094. https://doi.org/10.1037//0003-066x.34.11.1085

Urquiza-Haas, E., & Kotrschal, K. (2015). The mind behind anthropomorphic thinking: Attribution of mental states to other species. Animal Behaviour, 109, 167–176. https://doi.org/10.1016/j.anbehav.2015.08.011

Vandermassen, G., Demoor, M., & Braeckman, J. (2005). Close encounters with a new species: Darwin's clash with the feminists at the end of the nineteenth century. In *Unmapped countries: Biological visions in nineteenth-centry literature and culture*, pp. 71-81. Anthem.

Varma, S. (2006). Preliminary item statistics using point-biserial correlation and p-values. Educational Data Systems, 1–7.

Wagner, W., Kronberger, N., Nagata, M., Sen, R., Holtz, P., & Palacios, F. (2010). Essentialist theory of "hybrids": From animal kinds to ethnic categories and race. Asian Journal of Social Psychology, 13(4), 232–246. https://doi.org/10.1111/j.1467-839X.2010.01315.x

Watson, J. (1913). Image and Affection in Behavior. The Journal of Philosophy, Psychology and Scientific Methods, 10(16), 421. https://doi.org/10.2307/2012899

West-Eberhard, M. (1983). Sexual selection, social competition, and speciation. The Quarterly Review of Biology, 58(2), 155-183.

Wilson, M., Miller, C., & Crouse, K. (2017). Humans as a model species for sexual selection research. Proceedings of the Royal Society B: Biological Sciences, 284(1866). https://doi.org/10.1098/rspb.2017.1320

Ziadie, M., & Andrews, T. (2018). Moving evolution education forward: A systematic analysis of literature to identify gaps in collective knowledge for teaching. CBE Life Sciences Education, 17(1). https://doi.org/10.1187/cbe.17-08-0190

CURRICULUM VITA

Sarah Hamilton Spaulding

Department of Biology
University of Louisville
Louisville, KY 40208

EDUCATION	B.S., Biology Northern Kentucky University 2007-2012
	M.S., Forestry University of Kentucky 2012-2015
	M.S., Biology University of Louisville 2015-2018
	Ph.D., Biology University of Louisville 2018-2021
AWARDS	Dissertation Completion Fellowship Spring 2021
	Graduate Fellowship 2015-2017
	John W. Thieret Research Award 2012
	KAS Poster Competition – 2nd place 2009

RESEARCH

Hidden curriculum of gender essentialism
University of Louisville
Mentor: Dr Linda Fuselier
2017 – 2021

Microbial evolution and ecology
University of Louisville
Mentor: Dr Susi Remold
2015-2017

Chytrid fungus in KY salamanders
University of Kentucky
Mentor: Dr John Cox
2012 – 2015

Urban Water Quality
Northern Kentucky University
Mentor: Dr Kristine Hopfensperger
2011-2012

Forest Community Ecology
Northern Kentucky University
Mentor: Dr Kristine Hopfensperger
2010-2011

INSTRUCTION

Biology Honors Recitation
Graduate Teaching Assistant
University of Louisville, 2020

Introductory Biology, Majors
Graduate Teaching Assistant
University of Louisville, 2020

Environmental Biology
Instructor of Record
University of Louisville, 2019

Introductory Biology, Non-Majors
Instructor of Record
University of Louisville, 2019

Introductory Biology, Non-Majors
Graduate Teaching Assistant
University of Louisville, 2017-2020

Wildlife Biology
Graduate Teaching Assistant
University of Kentucky, 2014

Dendrology
Graduate Teaching Assistant
University of Kentucky, 2012-2013

Introductory Biology, Majors
Undergraduate Teaching Assistant
Northern Kentucky University, 2010-2012

OUTREACH

Urban Environment Community Service
Educator, Project Coordinator, 2019

Healthwise Summer Program
Educator, Volunteer, 2016-2017

PUBLICATIONS

Spaulding S. et al. (2018). Low-level Batrachochytrium dendrobatidis detection persists in Plethodontid salamanders following timber harvest in Kentucky, USA. Herpetological Review, 49(2): 258-262.

Fuselier L., Eason P., Jackson J., and Spaulding S. (2018). Images of objective knowledge construction in sexual selection chapters of evolution textbooks. Science and Education, 27: 479-499.

Spaulding S. (2015). An investigation into the occurrence of Batrachochytrium dendrobatidis infection in Plethodontid salamander communities of Robinson Forest. Theses and Dissertations – Forestry. Paper 22.

Hopfensperger K., and Hamilton S. (2015). Earthworm communities in previously glaciated and unglaciated eastern deciduous forests. Southeastern Naturalist, 14(1): 66-84.

CONFERENCES

"Sexual selection instruction: An Evaluation of relationships between theory pedagogy, gender self-stereotyping, and student misconceptions" Roundtable presentation scheduled to be given at NARST Annual Conference, canceled due to COVID-19, Portland OR, 2020

"Teaching sexual selection theory: Factors and approaches affecting conceptual understanding of sexual selection theory in undergraduates." SABER Annual Conference, Minneapolis MN, 2019

"Picturing sexual selection: Sex role representation in evolution textbook images." FEMMES Annual Conference, Corvallis OR, 2018

"An investigation of chytrid fungus infection in Plethodontid salamander communities of logged, surface mined, and intact forests of eastern Kentucky." The Wildlife Society Annual Conference, Pittsburg PA, 2014

"Dioramas in the classroom: Biodiversity outreach." ESA Annual Meeting, Pittsburgh PA, 2010