Now that gender and sexual diversity are more visible than ever, our science curriculum must adapt to serve our students and prepare them for the future. Among youth ages 13–18, 10.5% identify as lesbian, gay, or bisexual (Kahn et al. 2018) and at least 0.7% identify as transgender (Herman et al. 2017). Public awareness has grown to a point where 27% of Americans know someone who is transgender, and 45% view gender as a spectrum rather than a binary (n = 1306; Carmichael 2020). On television, one in 10 characters in the 2019–2020 broadcast season was LGBTQ (GLAAD 2020). Yet schools remain a place where youth experience daily bullying and harassment on the basis of sexual orientation or gender expression (Kahn et al. 2018).
Even teachers actively working against bullying may be surprised to learn about the impact of LGBTQ-inclusive curriculum on youth safety and learning. When a school implements LGBTQ-inclusive curriculum, students report less victimization, less absenteeism, and more positive relationships with their teachers (Kosciw et al. 2014; 2018). Yet this is exceedingly rare in science classes, with only 2.4% of LGBTQ students seeing any LGBTQ-inclusive science content in 2017 (Kosciw 2018). Lack of inclusive curriculum also impacts students’ career pathways—LGBTQ high school seniors who saw positive LGBTQ representation in science class were 17.3% more likely to choose a STEM major (n = 1124; Kosciw 2014).

High school biology teachers have rich opportunities to include gender diversity in our teaching. Inquiry lessons, by nature, allow students to create and discuss claims from evidence, and this can include claims about gender. When we teach genetics, we can highlight the complexity of genetic sex determination to add depth, rigor, and relevance to the lesson. When we teach evolution, we can include diverse animal reproductive strategies that make for captivating case studies. When we teach anatomy and physiology, we can expose students to data that challenges the notion of binary “male” and “female” bodies, and validates the complexity of human experience.

This article will outline a thinking framework that any teacher can use to adapt curriculum through a lens of gender diversity. We will illustrate the adaptation of several sample lessons to achieve three key outcomes: (1) to support and reduce harm to LGBTQ students, (2) to engage all students with inquiry into science in society, and (3) to develop student empathy toward diverse identities and perspectives. Additional resources are included at the end of the article to continue teachers’ explorations of creating inclusive classroom culture.

A Framework for Gender-Inclusive Biology
We use the five attributes of authenticity, continuity, affirmation, anti-oppression, and student agency to guide us in adapting any lesson to be inclusive of diverse gender, sex, or sexuality.

1. Authenticity – Provide accurate content and language that acknowledges both gender diversity and scientific precision. For example, “ovaries produce eggs” in meiosis, not “women produce eggs.” Ask: Is the content accurate or oversimplified?

2. Continuity – Consistently include gender, where applicable, as one of many lenses for analysis. Begin with a diversity lens instead of teaching an oversimplification that is later changed for exceptions. Ask: Do we have a consistently inclusive lens or a special token lesson?

3. Affirmation – Highlight and celebrate the naturally occurring diversity of human and nonhuman species. Frame diverse phenomena, such as chromosomal intersex traits, with interested curiosity. Do not sensationalize or pathologize these variations. Ask: Do we normalize or stigmatize variation?

4. Anti-Oppression – Encourage students to identify and analyze the patterns that inform society’s status quo. Help students recognize recurring injustices such as intersex genital mutilation, court-ordered sterilization and chemical castration of transgender and gay individuals, and sex verification in sports. Ask: Do we empower or marginalize groups?

5. Student Agency – Provide students choices and habitual incorporation of student feedback cycle. Students engage more when they explore their own questions and make decisions, especially in learning about gender, sex, and sexuality. Ask: Do we invite the sharing of student experience?

Key Terms for Gender, Sex, and Sexuality
Familiarize yourself and your students with these terms and concepts before beginning any activity where gender, sex, and sexuality may come up. See Online Resources for some graphical conversation starters that may help you introduce these terms to your students.

- Gender identity: A personal sense of one’s own gender. Self-determined and distinct from a person’s sex assigned at birth.

- Sexual orientation or sexuality: A person’s attraction toward men, women, both, another gender, or neither. Distinct from gender identity.

- Sex assigned at birth: The determination of a newborn infant’s sex as male or female, usually from inspection of the external genitalia by health care provider.

- Transgender: Broadly, any person whose gender identity is not fully aligned with their sex assigned at birth.

- Cisgender: A person whose gender identity is aligned with their sex assigned at birth.

- Intersex: Any person with sex characteristics that vary from the typical patterns of male or female development. Intersex people are born with these differences or develop them in childhood.
For example, lessons about skeletal development often include the classification of bones as “male” or “female,” oversimplifying forensic pathology techniques. When lessons reinforce how popular media misrepresents the use of bones as unquestioned “proof” of someone’s identity, we end up limiting the questions our students can pose. Sex classification systems are based on small samples of skeletons from one location, thus flattening details about the spectrum of sexual characteristics and morphology. For example, a common manual for skeletal pathology uses a system based on “49 adult skeletons from a 19th-century cemetery in Canada” (Bass 2005; Bone 1993).

Instead of rigidly classifying the sex of any human remains, we can guide students in questioning these models used by scientists. After learning about a male-classified human skeleton that was later found to have XX chromosomes, our students reflected on their own legacy and the physical evidence they’d leave behind for future scientists to interpret (Hendenstierna-Jonson et al. 2017). This links structure and function to other elements of everyday life by giving students an authentic connection to their learning and development (CCC).

The NRC also views science as an “evidence-based, model and theory building enterprise” (National Research Council 2013). A responsible approach to three-dimensional learning about gender requires we explicitly frame gender as a vital lens of inquiry for empirical data analysis. If students are given an opportunity to examine how sex hormones like estrogen and testosterone impact multiple organ systems, independent of gendered labels, they construct a deeper understanding of the phenomena first. They then compare this knowledge with social, medical, and academic stereotypes about gender and ability. Thus, students develop the skills, connections, and scientific knowledge to critically examine complex ideas and competing models that can bridge life experience and societal concerns. To illustrate some of these adaptations for authenticity, we provide a sample activity called “Modeling Patterns and Variations in Studying Human Skeletons” at http://bit.ly/biobones.

### FIGURE 1

**Building Continuity in Gendered Language.**

<table>
<thead>
<tr>
<th>Instead of...</th>
<th>Focus on...</th>
<th>Example</th>
<th>Why?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men/ Male Women/ Female</td>
<td>The organ, functional activity, or role</td>
<td>“Women Ovaries produce eggs.” “Males XY individuals are more likely to be color blind.” “The mother gestational parent carries the fetus for 9 months.”</td>
<td>All people, cis and trans, experience different bodies, reproduction, and families. Many organisms thrive in stable families where a male-female relationship is only one of many options.</td>
</tr>
<tr>
<td>Male/female hormones</td>
<td>Testosterone, estrogen, and progesterone</td>
<td>“Testes produce large amounts of testosterone.” “In an estrogen-dominant body, the bones develop like ...”</td>
<td>Testosterone and estrogen also regulate many non-sexual processes. Both hormones exist in most people of any sex with active gonads.</td>
</tr>
<tr>
<td>Normal Natural Typical</td>
<td>Patterns and probability</td>
<td>“In many species, the female provides more parental investment than the male.” “XX and XY are the most common combinations of sex chromosomes.”</td>
<td>Living things are diverse, with no one “typical” body or behavior. When discussing humans, many medical and scientific statistics only use data from white, cisgender, European populations.</td>
</tr>
</tbody>
</table>
**Continuity**

Students process many messages about gender diversity from their families, friends, media, and school. When we teach about gender, we must plan proactively to make sure our messages are internally consistent from lesson to lesson, while also acknowledging students’ experiences outside of biology class. For example, in a genetics unit, we may initially teach students that females have XX chromosomes and males have XY chromosomes because so many textbooks and lesson materials use this oversimplification. But some students will think and some will even ask out loud, “What if someone’s XX but they identify as a male because they’re transgender?”

The student’s question reveals our teacher oversight—we never formally defined “male” and “female” in the first place. When we realize this issue, we take a moment to clarify that when we say “male” and “female” in the genetics unit, we are referring to chromosomal sex, not gender identity. We may also acknowledge that some humans are not XX or XY, but students hear this as an “exception to the rule” because we are discussing it after we have already learned the rule.

What if, instead of teaching a simplification, we started each unit by defining sex and gender in context? For example, in genetics the important difference between “male” and “female” is in the X/Y chromosomes, but in an evolutionary context, the sexes are distinguished by their behavior or the size of their gametes instead. And in anatomy and physiology, “male” and “female” traits are often shaped by levels of estrogen and testosterone.

Gender-inclusive teaching requires continuity in the terminology and concepts taught from one lesson to the next. To provide continuity, we must consistently include gender, where applicable, as one of many lenses for analysis. This means beginning each unit of study with a diversity lens rather than teaching an oversimplification that will later require amendment. When we address gender diversity in a piecemeal, reactionary way or through a detached, one-time “very special lesson,” we miss the opportunity to make connections between multiple units of study.

When talking about gender, sex, and sexuality, our language should focus on the precise organ, function, or pattern being studied. In Figure 1, we suggest language updates for a typical high school biology curriculum. Even more hostile or reticent students and families can usually appreciate how greater precision helps us communicate in science.

**Affirmation**

When we normalize gender and sexual diversity in natural phenomena, we celebrate and affirm all student experiences through an inclusive, inquiry-focused lens. When students extend their critique of scientific models to chromosomes, hormones, and other gender-dense phenomena, they take a powerful step in analyzing how their own learning and construction of scientific knowledge affects their identity and community.

The National Research Council asserts that “science teachers need to acquire effective strategies to include all students regardless of ... gender backgrounds” (NGSS Appendix D).

When students see positive representations of naturally occurring diversity, they are empowered to pursue their curiosity. We as teachers can do so much by offering different models and phenomena without injecting prior misconceptions or incurious attitudes. Choose language that turns toward, not away from, diversity and complexity. Show students that myriad, naturally occurring families exist, such as same-sex swan couples who see 80% of their offspring survive to adulthood compared to only 30% of offspring from different-sex swan couples (Braithwaite 1981). Students can also see how gender expression is different from sex and chromosomes by exploring a game about meiosis and intersex traits. This normalizes student experiences without singling out any one student uncertain about their developing identities. In expanding our scope to recognize real phenomena, our striving toward NGSS requires we also acknowledge the flaws in a binary model.

The SEPs and DCIs under the NGSS also directly affirm student questions (and identities) that even the most prepared science teacher may be unable to predict. If students ask about eugenics and the idea of a “gay gene,” teachers can point to evidence of how same-sex behavior persists across species and all eras of human history, far more commonly than many other

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**Inclusive Classrooms in Any Subject Area**

Use these best practices to create a safer classroom culture for all students, whether you teach biology or another subject. In a safe and inclusive classroom, students will be more willing to ask about how gender, sex, and sexuality relate to the content they are learning.

- **Proactively learn your students’ names and gender pronouns on the first day of school.** Share how you would like to be called, then ask your students to introduce themselves, either publicly in class or on a private survey. If you must call out names from the roster before asking, call out last names instead of first names.
- **Listen to students and trust them as the experts on their needs.**
- **Openly acknowledge to your students when your own expression or behavior is uninformed or incorrect.** When given a clarification, respond with curiosity and not defensiveness—this is an opportunity to do better.
- **Highlight narratives of strength among marginalized groups.** Resist the urge to define marginalized groups by their trauma and tragedy.
- **Address casual offensive comments in the classroom promptly and firmly.** Focus on the harm done to the individual and community, and coach students in repeating non-harmful forms of expression.
genetic conditions (Roughgarden 2013; 256, cf. 284). On our website, we have compiled a Queer Species Database with hundreds of instances of diverse sexual behavior, sex, and gender. Teachers can pull from this body of evidence as needed to affirm student experiences regardless of their stated identity.

Although students and their families will hold varying perspectives on LGBTQ+ issues, teachers should encourage all to be curious and learn from gender diversity in biology. Diverse phenomena hold countless opportunities to strengthen our understandings in science, and they should not be framed as merely sensational or pathological "exceptions."

**Anti-Oppression**
Science is a human endeavor, and the ways we understand science and apply it societally can have lasting impacts on both individuals and groups (NSTA NGSS Appendix H: Nature of Science April 2013, p. 6). One part of creating a gender-inclusive biology curriculum requires identifying places where societal power and oppression impact specific marginalized gender groups, including transgender, intersex, and gender non-conforming people. Science involves describing and explaining phenomena, not prescribing what should happen in systems. Many decisions are not made using science alone, and the NGSS recognizes that scientists and engineers of "diverse backgrounds...rely on social and cultural contexts to resolve issues" (NSTA NGSS Appendix H: Nature of Science April 2013, p. 6). Involving our students in critiquing how scientific models are created and their social implications is only one way we can help dismantle structural inequities in science education (Bakshi 2020).

One excellent lesson that highlights these disparities is the Sex Verification of Athletes interactive created by HHMI Bio-Interactive. In this lesson, which targets NGSS Performance Expectations HS-LS1-2 and HS-LS3-1, students explore how biological sex has been defined and measured in sports throughout history. In the process, students develop a model to represent how intersex traits—such as differences in genital structure, gonads, and hormone synthesis or sensitivity—can arise from genetic inheritance. This lesson intersects with all parts of our framework, but especially highlights the ways that people with intersex traits have been mistreated, objectified, and ostracized from the athletics community based on differences that are natural and random.

**Student Agency**
Good teaching requires knowing our students well and listening to their feedback to adjust our teaching practice. This is especially true when creating a gender-inclusive curriculum that works in the specific context of our classrooms. While making shifts toward a gender-inclusive teaching model, it is valuable to ask your students what they are interested in learning about, and hear their questions and concerns. A regularly scheduled check-in for student feedback can be one step in creating a safer space for students to engage in questions and topics that may be deeply personal or challenging to discuss.

One way to involve students in the process of adapting your curriculum is to co-create language and diagrams that accurately describe the phenomena they are learning about (Figure 2). During a lesson on mitosis, for example, we are likely to encounter a diagram that shows silhouettes of a figure in a dress creating eggs and a figure in trousers creating sperm. When encountering this diagram for the first time, we can ask students to think about different ways of describing the process that are inclusive and universal. For example, egg creation occurs in ovaries, and sperm creation occurs in testes. By revising the model with accurate labels of the location of these processes, we...
eliminate inaccuracies and provide opportunities for students to be a part of creating their own learning materials, adding to their learning experience.

Similarly, during a lesson on pedigrees and genetic inheritance, the terms “mother,” “father,” and “biological parent” are often used to describe the two individuals who create the egg and sperm that become a new person. However, we know that the relationship of these three people cannot always be described by those words—for families who adopt, use surrogacy or donor gametes, or see a parent transition gender, these terms may directly contradict the way they describe themselves. This idea of “the two individuals who created the egg and sperm that became a new person” has no official, accurate, and inclusive name in the English language. So this is a great opportunity for students to co-create language that accurately describes this idea. In the past, students have come up with words such as “Biological Life Transmitters” (BLTs), “Gene-Givers” (GGs), or “Storks,” since these cells “bring” the baby. This is a rare opportunity for the students to teach language to the teacher rather than the other way around, and models the way that science and language are constantly shifting to be more accurate and inclusive. Student agency allows students to take ownership in what they are learning, and for students with high interest in these topics to explore them even further.

Objections to Gender-Inclusive Biology Teaching

We recognize that each of our readers teaches in a unique setting and must adopt gender-inclusive teaching practices in a way that fits their school community. Many teachers worry that their administrators or students’ families will raise objections to teaching about gender, sex, and sexuality in biology class. In Table 1 (see Online Connections), we address some common objections and offer solutions-focused responses and resources.

Conclusion

This overview demonstrates how teachers can use the five elements of the Framework for Gender-Inclusive Biology Curriculum to make high-impact adaptations to their biology lessons. Adaptations can be as simple as substituting one term for a more precise and inclusive term. Adaptations can also be more involved, such as a multiday inquiry on how binary sex classifications are oppressive to intersex athletes. These adaptations achieve three key outcomes: (1) to reduce harm and support LGBTQ-identified students; (2) to engage all students with opportunities to share ideas and construct their social understanding of scientific evidence; and (3) to develop student empathy toward diverse identities, perspectives, and scientific ethics. Although our examples focus on high school biology topics, we believe the framework can also be used to create and adapt curriculum in K–8 science and in other content areas.

When we intentionally teach about gender in biology, we are able to shape the way students understand themselves, science, and society. One of our students who identifies as transgender said, “Your class is the reason I know what I want my career [in STEM] to be, and that means a lot to me.” One intersex student cited a gender-inclusive biology course as “one of the motivations that makes me believe school isn’t just a hell hole.”
Teaching Outside the Binary (Middle school focus)

• The Gender Triangle by GLSEN & InterACT

• Gender Galaxy: Graphical conversation starters for teaching key terms for gender, sex, and InterACT: Advocates for Intersex Youth

https://www.interactadvocates.org

• Gender Spectrum

• GLSEN Educator Resources

STEM Teaching Tools Practice Brief: www.stemteachingtools.org/brief/76

Teaching Outside the Binary (Middle school focus) www.teachingoutsidebinary.com

GLSEN Educator Resources www.glsen.org/resources/educator-resources

Gender Spectrum www.genderspectrum.org

InterACT: Advocates for Intersex Youth https://interactadvocates.org

Graphical conversation starters for teaching key terms for gender, sex, and sexuality:

• Gender Galaxy: https://www.actioncanadashr.org/beyond-basics-sneak-peek-gender-galaxy

• The Gender Triangle by GLSEN & InterACT https://www.glsen.org/activity/gender-triangle-education-guide

ONLINE RESOURCES FOR GENDER-INCLUSIVE BIOLOGY TEACHING

The Gender Inclusive Biology Project: free classroom-ready lessons and resources for K–12+, curated by the authors of this article. www.genderinclusivebiology.com.

Gender Inclusive Classrooms (Elementary school focus) www.genderinclusivebiology.com

ONLINE CONNECTIONS

Table 1: Common Objections to Gender-Inclusive Biology Teaching https://bit.ly/31jVjb

GENDER-INCLUSIVE BIOLOGY: A FRAMEWORK IN ACTION

A cisgender ninth grader said after a gender-inclusive meiosis activity, “This makes much more sense because lots of different people are out there and this way you understand better when you meet someone new.”

Classroom teachers and workshop attendees remark that they appreciate the authenticity and rigor that a gender-inclusive curriculum provides. We believe that teaching gender and sexual diversity in the biology classroom is a natural fit and better reflects real-world science and engineering practices. As one student concluded: “It’s biology, and if we wanna be talking about people, we have to be talking about all people.”

ONLINE RESOURCES FOR GENDER-INCLUSIVE BIOLOGY TEACHING

The Gender Inclusive Biology Project: free classroom-ready lessons and resources for K–12+, curated by the authors of this article. www.genderinclusivebiology.com.

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• The Gender Triangle by GLSEN & InterACT https://www.glsen.org/activity/gender-triangle-education-guide

REFERENCES


Sam Long (sam.long.mt@gmail.com), Lewis Steller, and River Suh are science teachers who maintain the free resource website GenderInclusiveBiology.com. They also hold workshops at conferences and in preservice teaching programs.

www.nsta.org/highschool