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Inheritance and Inclusion: Teaching Genetics for All Students

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ABSTRACT

Although we do not know the exact number, some students in our classrooms are not living with caregivers genetically related to them. There are various reasons this occurs: adoption, fostering, surrogacy, and blended families. For example, The Adoption History Project (2012) estimates that 5 million Americans are adopted. About 2.5 percent of all children under 18 are adopted. Given the number of students in our K-12 classrooms who are not living with a genetically related caregiver, teaching genetic concepts requires utmost care. We should remember that investigations that ask students to compare inherited traits with those of the adults they live with, such as eye color, ear lobes, or tongue rolling, can create confusion and angst. Students may feel pressured to lie to conceal that they do not live with a genetically related caregiver. Studying genetics is complex, and for students without genetically related relatives, it can stir feelings such as grief, loss, and confusion. This paper describes an inclusive approach to teaching genetics to elementary-aged children with sensitivity and care.

Keywords: genetics education, inclusive pedagogy, adoption, elementary science, Next Generation Science Standards, culturally relevant pedagogy

Introduction

Heredity and genetics are among the most challenging topics for students to understand (Galea, 2016). Students often lack a clear understanding of how genes and chromosomes influence inheritance and variation. Many students believe traits from parents are blended within their offspring. Others think inherited traits are gender-specific, with stronger traits from mothers in females and fathers in males. Students also incorporate environmental factors in their understanding of variation, attributing population variation to the environment rather than sexual reproduction (Driver et al., 1994).

Understanding genetics is an international imperative. Genetics is an integral part of daily life, informing one's health care (Mills-Shaw et al., 2008). It also raises important ethical questions. The completion of the Human Genome Project and widespread efforts to map the human genome mean humans are quickly becoming the best-understood genetic system (McGowan, 2005; Redfield, 2012). As a result, home genetics testing kits from companies like Ancestry.com and 23andMe are increasingly popular. Students must be informed consumers, able to make informed decisions about whether or not to know their DNA (Redfield, 2012). To make informed choices, students need to understand the basic principles of genetics (Nowgen, 2012). Recognizing this, genetics is part of most school curricula, including elementary schools (Kiliç & Sağlam, 2014; Aldahmash & Alshaya, 2012; Knippels et al., 2005). However, even though today's students are regularly exposed to genetics, many cannot understand the subject well enough to apply it in their own lives (Lewis & Wood-Robinson, 2000).

Teaching and Learning Genetics in the Next Generation Science Standards

The Next Generation Science Standards (NGSS) offer guidelines for teaching genetics through performance expectations by grade level. The NGSS (2013) emphasizes understanding the principles of genetics and applying them to real-world situations. In elementary school, students learn about traits, variation, and how genetic information passes from parents to offspring. NGSS also calls for students to study genetic diversity and its role in species' survival. In middle school, students study the structure and function of DNA and how it carries genetic information. They also learn about genetic mutations and how they affect traits and diseases. In high school, students explore the mechanisms of gene inheritance, including meiosis and the role of chromosomes. They also learn about genetic engineering and biotechnology, including the ethical considerations in manipulating genetic material.

At all levels, NGSS emphasizes scientific practices such as modeling, explanation, and argument from evidence to deepen learners' understanding of genetics. NGSS highlights crosscutting concepts such as patterns and cause-and-effect. These concepts help students make connections across science.

The Application of the Next Generation Science Standards

NGSS guidelines do not require examples of human genetics. However, search of online instructional resources reveals many lessons that ask students to trace physical traits through familial lines. Lessons ask students to examine traits like hair color, eye color, and height to learn that genes are passed from parents to offspring. Students build family trees to explore how traits are inherited. They identify inheritance patterns and see that some traits are more common in certain families.

However, there are instances of authors critiquing this human-centric approach. In a 2016 article, Galea critiques a lesson she delivered in her class. The lesson centered on the lives of fraternal twins Lucy and Maria Aylmer, whose father is white and whose mother is half-Jamaican. As students worked on the lesson and the culminating pedigree project, Galea overheard several say they did not know their families or were adopted. She observed that many students decided to make up a pedigree for a pretend family. For these reasons, Galea no longer asks students to create a pedigree of their own family. Now, she asks them to create one for a fictional family.

As an adult adoptee, I can personally relate to the feelings of Galea's young students. I vividly remember being asked to trace my brown eyes to my blue-eyed parents and grandparents. As an adult, I now understand that the inheritance of eye color is complex. It is possible that I could have inherited my brown eyes from two blue-eyed parents. However, as an elementary-aged student, trying to present my eye's phenotype through Punnett Squares of so-called big Bs and little Bs, it was always easier to invent my pedigree to avoid uncomfortable conversations with my teachers and peers.

The Importance of Preservice Elementary Teacher Candidates: Ms. Graham

Each semester, I teach a full-semester, three-credit elementary science methods course to undergraduate and graduate-level preservice elementary teachers. I frame the course around the Next Generation Science Standards and Culturally Relevant Pedagogy (Ladson-Billings, 2021). In each class, I require my students to confront the myriad of deficit perspectives in our educational world. Through readings, class discussions, and assignments, I elevate the lived experiences of students who have historically been marginalized by our educational institutions and push my students to identify and implement culturally sustaining practices. I intentionally elevate the lived experiences of students who are not genetically related to their caregivers, including adoptees, and challenge my students to intentionally create opportunities to include instructional moments that affirm students who may not be genetically related to their caregivers. I caution my students that this must be done with the utmost care and sensitivity so as not to "call out" students but to provide space for healthy exploration. At the very least, teachers should not implement lessons requiring students to document their genetic lineage. Lessons that ask students who do not live with a genetically related caregiver to trace their own genetic lineage can stir various emotions, including grief, loss, and confusion, and should no longer be taught in the K-12 classroom.

Recently, one of our students, Ms. Celia Graham, developed a four-lesson mini unit for my class that skillfully presented genetics to elementary-aged students, eliminating human examples of inheritance. Ms. Graham framed the storyline of her mini-unit to the anchoring phenomenon of inherited traits in animals, aligning with the NGSS standard 1-LS3 Heredity: Inheritance and Variation of Traits: make observations to construct an evidence-based account that young plants and animals are like, but not exactly like, their parents. The four lessons, written in the 5E lesson format, refined students' understanding of physical traits while developing their understanding of how traits can be passed from parent to offspring, using pea plants, dogs, and cats to illustrate heredity.

Lesson One: Observing Physical Traits Through Description

Ms. Graham began her unit with a brief exploration of observable characteristics, laying the groundwork for understanding physical traits. Using a KWL chart to elicit prior knowledge, she guided her first graders in thinking about the appearances of living things. Without formally naming the scientific concept, students described their peers' appearances on a provided worksheet organized with sentence starters. The class discussion, supported by an anchor chart and talk moves like "tell me more," scaffolded students' thinking, helping build a shared understanding. Only after this building of shared understanding did Ms. Graham introduce the scientific term physical trait, anchoring the vocabulary term in students' observations. This approach allowed students to construct an understanding of physical characteristics before scientific vocabulary was introduced.

Ms. Graham noted that this foundational lesson helped build students' understanding of physical traits. She noted that some students initially believed that physical traits included one's personality or one's clothing, but through individual conversations, Ms. Graham was able to redirect students' understanding to observable, inherited traits. She was especially encouraged by students' ability to express similarities and differences within animal families and felt that this lesson set a strong stage for the more complex ideas explored in lessons two through four.

Lesson Two: Modeling Inheritance Using Animal Parents and Offspring

In the second lesson, students applied their understanding of traits by predicting how traits might be inherited from animal parents. Each child received a worksheet depicting two "parent" animals and was asked to draw or describe an offspring that inherited physical characteristics from both. Differentiated options, including drawing, writing, or speaking, supported the participation of many learners. Ms. Graham led the students in a whole-class discussion, supporting them as they informally presented their findings and critiqued nonexamples of offspring that did not resemble their parents. This lesson reinforced students' understandings that offspring inherit traits from both parents, building early reasoning skills in genetic inheritance.

Ms. Graham found that her students were significantly engaged in this lesson and improved at retaining scientific vocabulary from the first lesson. Students provided evidence of logical reasoning, and Ms. Graham observed that the lesson successfully built on students' prior knowledge while introducing the concept of inherited combinations in an inclusive way that did not include human pedigrees.

Lesson Three: Investigating Trait Patterns with Pea Plant Models

The third lesson of the mini-unit offered a hands-on investigation of inheritance patterns using illustrations of pea plants at different life stages. Rotating through four stations, students observed and recorded the traits of "parent" plants and their "offspring," noting variations in seed color and flower color. In some scenarios, both parents shared a trait (e.g., green seeds or purple flowers), while in others, the offspring exhibited variation from the two different parent traits. Students worked in collaborative groups to document their observations through words or drawings. At the end of the lesson, Ms. Graham facilitated a discussion to help students recognize patterns and make inferences, posing questions like, "Could a green pea and a yellow pea make a purple pea?" The lesson emphasized observation, classification, and evidence-based reasoning, while solidifying the connection between parental traits and inherited outcomes.

Ms. Graham reflected that using plants helped reinforce the concept that inheritance applies to all living things, not just animals. Her students recorded accurate observations, identified traits such as "wrinkled" or "green," and began making informed predictions about inheritance patterns. Ms. Graham noted that this lesson deepened their understanding while providing a more inclusive lens through which to view genetics.

Lesson Four: Synthesizing Understanding Through Family Trait Sorting

In the final lesson, Ms. Graham's students synthesized their learning by sorting a set of cat images into family groups based on shared physical traits. Working in small groups, her students arranged two adult cats and two kittens into family units on a poster, making sure that offspring inherited a blend of traits from both parents. The students were asked to justify their choices in writing, using trait-based language. This exercise reinforced the idea that physical traits are inherited and that offspring typically exhibit a mix of parental traits. In a whole-class wrap-up, students presented their posters. This final lesson served as both an assessment and a celebration of student learning in a culturally sensitive, scientifically grounded genetics unit.

Ms. Graham reflected that the lesson supported scientific discourse while providing her with multiple opportunities to clarify her reasoning. Especially noteworthy was one group's struggle to explain the transmission of physical traits from parent to offspring, which led to a productive discussion that reinforced greater understanding for the entire class.

Discussion and Considerations

The teaching of genetics and inheritance in K–12 classrooms must be approached with care, particularly given the increasing number of students who do not live with genetically related caregivers. The research literature demonstrates that much of the research on genetics is highly human-centric, excluding or stigmatizing students in adoptive, foster, or blended families (Galea, 2016). Foundational science concepts like heredity and variation must be taught with both scientific rigor and emotional sensitivity, ensuring that no student feels isolated by curriculum choices. This imperative has been echoed in both personal narratives and scholarly critiques, underscoring the need to reform how genetics is introduced at the elementary level.

The work of Ms. Celia Graham illustrates how such reform can take place in practice. Her thoughtfully designed four-lesson unit, aligned with NGSS standard 1-LS3, avoided the pitfalls of human-centered examples and instead used animals and plants to foster students' understanding of traits and inheritance. This unit models how educators can center inclusion without sacrificing academic integrity. The unit's emphasis on physical traits, scientific discourse, and observational evidence encouraged students to develop foundational reasoning skills while reinforcing that heredity applies to all living organisms, not just humans.

Each lesson in the unit was built thoughtfully upon the last. Students began by identifying and describing observable traits, constructed an understanding of how traits are inherited through modeled scenarios, and engaged in hands-on investigations to observe trait variation. The final lesson provided opportunities for synthesis, as students grouped animal families based on inherited traits, while articulating their scientific reasoning. The entire unit provided opportunities for formative assessment and was rich with student discourse. Most importantly, the lessons were sensitive to the diverse family structures represented in today's classrooms, reinforcing the concept of genetic inheritance through universally accessible examples.

As Ms. Graham planned this unit, she found many ancillary materials that used human examples to illustrate inheritance, examples that could be emotionally harmful to children being raised by non-genetically related adults. However, books such as *The Secret Code Inside You* and *Genetics for Smart Kids* provide concrete, engaging explanations of complex topics like DNA and heredity through vibrant illustrations, accessible language, and non-human examples. When students are invited to read, write, speak, and think about science in multiple ways, their understanding deepens and becomes more transferable.

Ms. Graham's reflections show that her students not only engaged with the science content but also began to articulate their understandings using scientific vocabulary and logical reasoning. The unit's inclusive nature encouraged broad participation and supported the development of key science practices, such as asking questions, constructing explanations, and engaging in argument from evidence. The lessons also provided multiple entry points for diverse learners, including opportunities for oral, written, and visual expression. Her reflections suggest that inclusive science instruction can enhance not only understanding but also student confidence and engagement.

Ms. Graham's unit can also be understood as an exemplar of culturally responsive NGSS storylining in practice. Rather than anchoring learning in personal family pedigrees, an approach that can unintentionally marginalize students whose family structures do not align with genetic lineage, the unit centers universally accessible phenomena in plants and animals. This design preserves the coherence and sensemaking goals of NGSS storylines while ensuring identity-safe participation for all learners. By beginning with observable traits, building toward pattern recognition, and culminating in evidence-based explanations, the storyline supports conceptual understanding without requiring personal disclosure. In doing so, it demonstrates that culturally responsive story lining is not an add-on to science instruction but an essential feature of equitable sensemaking.

Our work also extends the literature on culturally responsive science teaching by foregrounding the diversity of family structures as an equity consideration in elementary genetics instruction. While culturally responsive pedagogy often emphasizes linguistic, racial, and community knowledge, this intervention highlights how normative assumptions about families embedded in curriculum materials can create barriers to participation and belonging. Ms. Graham's design illustrates how preservice teachers can learn to identify these hidden assumptions and make intentional instructional decisions that affirm diverse lived experiences while maintaining scientific rigor. Her planning process and reflections suggest that developing culturally responsive science instruction requires structured opportunities for preservice teachers to analyze curricular norms, anticipate student experiences, and design inclusive phenomena-based investigations.

Finally, for teacher education programs and curriculum designers, this work offers both practical guidance and a call to action. Preparing preservice teachers to design culturally responsive NGSS storylines should include modeling inclusive anchoring phenomena, providing tools for eliciting and honoring diverse experiences, and creating collaborative design spaces where future educators can critique and revise traditional lessons. At a broader level, teacher preparation programs, districts, and professional organizations should invest in the development and dissemination of identity-safe science resources that support belonging and participation in science learning. Designing inclusive storylines is not simply a matter of sensitivity; it is central to fostering equitable access to science practices and to supporting all students in seeing themselves as capable participants in scientific sensemaking.

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