Amgen Award for Science Teaching EXCELLENCE

2008
Winning Lesson Plan
from Berkeley, California

Exploring Human Ancestry by Uncovering Our Own Genetic Origins

by Elisa M. Stone
Berkeley High School

Subject: Biotechnology
Grade Level: 12
Duration: 1 week lesson, within a 10 week unit

Overview and Purpose

This lesson extends and advances the "What Is Race?" unit that I have taught with much success in my biotechnology class for several years. In this unit, students explore one of the most important social issues of our time—race—by interpreting data from their own experiments on skin color, hair, DNA and blood type. Students will learn new experimental skills, forensics methods, DNA sequence analysis, and concepts of heredity and the history of human migration. In the new lesson that I propose here, students will analyze their own genes to track their ancestry, as participants in the cutting edge National Geographic "Genographic" program. I believe it will be particularly powerful for the students to learn this material, not by watching a video of someone else's discovery, but by working hands-on with genetic data that allows them to discover their family's ancestral origins for themselves.

Context of Course

The Biotechnology course that I teach is the second year of a two-year program called the Biotechnology Academy, designed to train at-risk students for a career in the biotechnology industry. In the first year, 11th grade students are trained in concepts and skills they will need for a summer internship in a local biotech company. During their 12th grade, students are taught advanced concepts and experimental skills, preparing them for careers and college courses in biotechnology, medicine, engineering and scientific research. I work closely with the teacher for the 1st year of the program, and staff at a non-profit organization called the Biotech Partners that is associated with Bayer, a local biotech company. Biotech Partners organizes and supervises student internships and jobs, offers tutoring programs, and supports students that continue in the community college program. The "What Is Race?" unit is of particular interest to our class because it is made up predominantly of students of color. Students identify with a wide variety of races, including students of African-American, Asian, Latino, White and mixed race, which offers an ability to collect a variety of data from the class itself.

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Goals for the Unit

In the "What Is Race?" unit students explore concepts of race from the perspectives of society and science, perform experiments that address the question of whether race can be defined using biotechnology, and review concepts of DNA structure, replication, and heredity:

Weeks 1 and 2:

Introduction to Race and Forensic Analysis (and the Genographic Project)

- Students brainstorm how we define race, categorize different races, and the role that science plays in answering important social questions. Students formulate hypotheses about whether biotechnology can define me or not, and why. Students examine class data with human skin color charts, use the microscope to classify human hair, collect samples using guidelines for human subject confidentiality, and practice forensic analysis in a set of four laboratory experiments to address the question of whether skin color and hair analysis can be used to distinguish different races. (In preparation for the new lesson in week 8, students will be introduced to the National Geographic's "Genographic" Project, sign up for individual kits, and submit parental permission to participate.)

Weeks 3 and 4:

DNA Structure and Replication

- Students review the molecular structure of DNA, learn how DNA is replicated, design and build a detailed 3-dimensional physical model of the double helix and replication fork, and critique their own and classmates' models. (In preparation for the new lesson in week 8, students will isolate their own cheek cells to obtain DNA, and mail in the Genographic kit.)

Weeks 5 and 6:

Polymerase Chain Reaction (PCR)

- Students understand how PCR works, review DNA electrophoresis, isolate DNA from their own hair follicles, perform a PCR experiment, and use chi-square statistical analysis of a large data set to answer the question of whether DNA analysis can differentiate different races.

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Goals for the Unit (Cont'd)

Week 7:

Heredity and Blood Type

- Students review genetics and heredity of simple and complex traits, learn how blood type is inherited and why blood type is important for blood transfusions, perform a blood type experiment using simulated blood, and analyze blood type data from many groups of people around the world to determine if blood type can be used to distinguish different races.

Week 8 (Proposed New Lesson):

Heredity, Human Ancestry and Human Migration

- Students will use their own DNA sequence results from the National Geographic "Genographic" project to learn how DNA sequence comparisons are made, discover where their ancestors originated and how they arrived in California and learn about global human migration patterns to further define their understanding of race and ethnicity (see "Procedures" section on page 6 for more details).

Weeks 9 and 10:

Can Race Be Determined Using Biotechnology?

- Students engage in discussions about the implications of race as a social construct, and the role of science in defining race, after watching the PBS special "Race: The Power of an Illusion". Students develop an argument to prepare for a final exam essay addressing the question "Can race be determined using biotechnology?" In the essay, students support their claim with evidence from their experiments from the entire unit.

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Educational Standards Addressed

Our Biotechnology course standards are drawn from the California Science Content Standards for Biology, Chemistry, and Investigation and Experimentation. These California standards closely match those found within the National Science Education Standards (EJSES) Life Sciences Content standards, with the exception of additional NSES for the History and Nature of Science listed below. The standards are for the entire unit, as independent lessons work together to achieve the gods for the unit as a whole.

California Biology Standards (1.b.) Students know enzymes are proteins that catalyze biochemical reactions without altering the reaction equilibrium and the activities of enzymes depend on the temperature, ionic conditions, and the pH of the surroundings, (1.h.) Students know most macromolecules (e.g., nucleic acids) in cells and organisms are synthesized from a small collection of simple precursors. (2.c.) Students know how random chromosome segregation explains the probability that a particular allele will be in a gamete. (4.) Genes are a set of instructions encoded in the DNA sequence of each organism (5. a.) Students know the general structures and functions of DNA. (8.c.) Students know the effects of genetic drift on the diversity of organisms in a population.

California Chemistry Standards (10.a.) Students know large molecules (polymers), such as nucleic acids, are formed by repetitive combinations of simple submits. (8.b.) Students know how reaction rates depend on such factors as concentration, temperature, and pressure. (8.c.) Students know the role a catalyst plays in increasing the reaction rate.

California Investigation and Experimentation Standards (1.) Scientific progress is made by asking meaningful questions and conducting careful investigations. Students should develop their own questions and perform investigations in which they (1.c.) Identify possible reasons for inconsistent results, such as sources of error or uncontrolled conditions. (1.d.) Formulate explanations by using logic and evidence. (1.h.) Read and interpret geologic maps. (1.j.) Recognize the issues of statistical variability and the need for controlled tests.

National Standards for History and Nature of Science (Science as a Human Endeavor) Scientists are influenced by societal, cultural, and personal beliefs and ways of viewing the world. Science is not separate from society but rather science is a part of society. (Nature of Scientific Knowledge) Scientific explanations must meet certain criteria. First and foremost, they must be consistent with experimental and observational evidence about nature, and must make accurate predictions, when appropriate, about systems being studied. They should also be logical, respect the rules of evidence, be open to criticism, report methods and procedures, and make knowledge public.

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Educational Standards Addressed (Cont'd)

Explanations on how the natural world changes based on personal beliefs, religious values, superstition, or authority may be personally useful and socially relevant, but they are not scientific.

Note: I have never been able to meet these final standards outlined by NSES with the success that this unit has been able to achieve, and will reach all the better with the additional lesson proposed.

Objectives of Lesson

Students report that they learn a lot from the "What Is Race?" unit. Moreover, in my opinion their final essays reflect a deep understanding of the scientific process, of the experiments we did in class, and of the extent to which race is a social construct that cannot be defined adequately by techniques in biotechnology. The goals and standards listed above are met with the unit as it is; however, upon seeing the PBS specials that we watch in class, many students have asked me if they can do more extensive analysis to learn more about their own ancestry. In other words, students are inspired to learn more and are requesting the very resources that I have outlined in my proposal here. Specifically, by engaging in this additional lesson, students will achieve an understanding of DNA sequence analysis, learn about where their ancestors originated, and gain appreciation of how patterns of heredity and centuries of human migration make up the variety in physical appearance that we see in people around the world.

Materials

Materials listed for "What Is Race?" unit are already available. We do not presently have access to the materials for the new lesson proposed:

- Heredity, Human Ancestry and Human Migration Lesson
  - National Geographic "Genographic'' kits
- "What Is Race?" unit
  - Skin Color Charts, Microscopes, Human Hair samples, "DNA Interactive" DVD, DNA modeling tools and supplies, BioRad PCR Alu kit, PCR Machine, DNA Gel Electrophoresis equipment, Boreal blood typing kit, PBS specials on race "African American Lives" and "Race: Power of an Illusion" DVDs

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Procedures

1. Early in the unit, students will be introduced to the National Geographic's "Genographic" Project with their engaging video and a discussion in class, and by spending a day in the computer lab on their excellent web site. They will be asked to develop a written proposal for why they want to participate in the Genographic project, seek parental permission to participate, and sign up for individual kits.
2. After the materials arrive, students will isolate their own cheek cells to obtain DNA, and mail in the Genographic kit. The National Geographic staff states that they return the results within 4 weeks.
3. Students will analyze their own DNA sequence results. First they will compare their sequence with other sequences on line, and learn what human "haplotype" their DNA belongs to. Female students will trace their maternal line through mitochondrial DNA sequences, and male students will have the choice of tracing their maternal line, or their paternal line through their Y chromosome DNA sequences. The analysis will take place over 2 days in the computer lab. Students will summarize their findings in their lab notebooks, and describe their process of discovering their ancestry and the history of the migration of their family line.
4. Students present what they learned to the class, and we will make a class data table together summarizing the class results. The table will include how the students identify by race or ethnicity, and list any surprises that individual students found.
5. We will watch the final segment of the Geographic video on human migration, after which I will use the data table from both biotech classes (sample size of about 50 students) to hold a class discussion on patterns of global human migration patterns. After the discussion students will write a reflection of how their understanding of race has changed or increased (or stayed the same, as the case may be), using evidence from their results and their classmates results to support their claims.
6. Students will create a print-out of all of their data analysis, and submit materials for a class data set to be used in future years. In the future, I intend to find additional funding for current students as well as use class data from past years.

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Activities Outside the Classroom

Students keep a detailed laboratory notebook, organized according to industry standards, for experimental work in class. Making a flow chart to simplify experimental procedures is required before performing all experiments, and is completed outside of class. Experimental conclusions include answering the experimental question with specific data they have obtained, describing sources of error that may have influenced their data, and ideas for follow-up experiments. Proposals for participating in the study, as well as rough drafts of the final essay will be done outside of class. One of the cheek cell isolations will be done in class, and another will need to be done 8 hours later at home.