Teaching About Genetics and Sickle Cell Disease in Fifth Grade

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Abstract: A 5-lesson, 5th-grade instructional unit, "Genetics and Sickle Cell Disease," was developed and tested as part of a 40-lesson curriculum entitled SEEK (Science Exploration, Excitement, and Knowledge): A Curriculum in Health and Biomedical Science for Diverse 4th and 5th Grade Students. The genetics lessons include hands-on activities (e.g., DNA extraction from cheek cells), a simulated plant genetics experiment, and a classroom visit by a person with sickle cell disease, as well as by a health care practitioner who works with sickle cell patients or a scientist specializing in genetics. The unit was tested with 82 5th-grade students at public elementary schools in Oakland, CA; 96% were racial and ethnic minorities. The comparison group consisted of 84 5th-grade Oakland students racially/ethnically, academically, and socio-economically matched to those in the experimental group. Both groups completed a 20-question, multiple-choice pre/posttest covering science concepts, scientific process, lifestyle choices, and careers. The experimental group showed significant improvement on 13 of 20 questions ($P<.05$, t-tests) and on the test as a whole, whereas the comparison group did not show significant improvement either on any of the questions or on the test as a whole. The experimental group improved on 10 concept questions, 2 scientific process questions, and 1 lifestyle question. Teachers rated the educational value of the unit as 9.5 on a scale from 1 (low) to 10 (high). These results show that genetics and sickle cell disease can be taught successfully in 5th grade, although they are not typically covered at this level.

Keywords: genetics ■ sickle cell disease ■ elementary school ■ fifth grade

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INTRODUCTION

Understanding how health and well-being can be optimized throughout life requires some knowledge of genetic science. Thus, most states have curriculum content standards that include genetics and related topics. Typically, however, most genetic concepts are not taught until secondary school. The need to improve K-12 education in genetics, because it is essential to enhancing public understanding of genetics and genomics and promoting health, is pointed out in a 2010 report prepared for the US Secretary of Health and Human Services.[1]

It has long been known that genetic counseling can be insufficient for imparting genetic information. In 1974, Hampton. Anderson, and Lavisso[2] found that in a survey of 47 families who were counseled about sickle cell anemia after their children had tested positive for the trait, 43 percent thought that the existence of the trait was a disease, and about half thought that their children's activities needed to be severely restricted.

In a study of 1,880 students, including 138 in 5th and 6th grade, Jones, Smith, and Calvert[3] showed that in-service teacher training by sickle cell education staff enhanced student learning about sickle cell disease: students whose teachers received such training did better than students whose teachers were given the same sickle cell curriculum to use in the classroom, but without instruction on how to use it.

In the present study, college-age presenters were trained to teach "Genetics and Sickle Cell Disease," a 5-lesson, 5th-grade instructional unit in *SEEK (Science Exploration, Excitement, and Knowledge): A Curriculum in Health and Biomedical Science for Diverse 4th and 5th Grade Students.*[4] In addition, teachers attended presentations by sickle cell education staff and genetics researchers, and these professionals came to some of the classrooms for the final lesson. The purpose of the study was to demonstrate that basic concepts in genetics and culturally relevant information on sickle cell disease can be effectively conveyed to racially and ethnically diverse 5th grade students in a relatively low-performing, large urban school district serving low-income neighborhoods.

The Genetics Unit

Each lesson has a worksheet on which students record their observations as drawings, in writing, or in tables. The lesson plans and worksheets are available free online at http://www.chori.org/Education/SEPA/SEPA_curriculum.html. They are also available in a book that can be purchased from Amazon.com: *SEEK (Science Exploration, Excitement, and Knowledge): A Curriculum for Diverse 4th and 5th Grade Students*. All proceeds from the book go to support community health education projects.

Lesson 1: DNA and Your Cells

Students explore and describe physical characteristics of people. They differentiate between traits that have been inherited from parents and traits acquired by accident or on purpose, such as scars and ability to play a musical instrument. Then they work in pairs to prepare and examine slides of onion skin and to examine pre-prepared slides of animal tissue using handheld microscopes. The worksheet asks them to observe and draw what they see in the microscope. They compare the plant and animal cells, and they find the nuclei, where DNA is stored. Then they are shown a molecular model of DNA and told that the traits they inherit from their parents are encoded in DNA.

Lesson 2: See Your DNA

Students extract and observe DNA from their own cheek cells using a procedure that requires careful measurements and following instructions sequentially. The worksheet asks them to describe what they observe as they follow this procedure. After discussing their results, they assemble strings of beads that represent strands of DNA, and they compare their strands with a molecular model of DNA.

Lesson 3: Plant Parenthood

In an activity first described in *SPACES: Solving Problems of Access to Careers in Engineering and Science* (Lawrence Hall of Science, 1982),[5] students simulate a plant genetics experiment using 2.54-cm x 6.35-cm cards to represent dominant and recessive traits in flowering plants. Every parent plant has three gene cards in this activity: one for height, one for flower color, and one for seed shape. Each characteristic has two types of genes or traits: TALL and short; RED and white; ROUND and wrinkled. Dominant genes are in ALL CAPITAL letters and recessive genes are all lowercase letters. Figure 1 shows how to make cards for two parent plants. Each card has one gene on the front and one gene on the back. The students make the cards themselves, shake them in a bag, and dump them onto a desk or table. The genes that land face up determine the traits of an offspring. Students record and count the number of offspring with given traits and determine the probability of the various possible genotypes and phenotypes.

Lesson 4: Trait Inheritance

The students use Mr. Potato Head toys to reinforce their understanding of dominant and recessive genes. They observe a Mr. Potato Head and decide if an offspring could inherit various traits. "Dominant" and "recessive" are assigned arbitrarily to traits such as ear shape and nose color. Flipping two coins for each trait, with heads representing dominant genes and tails representing recessive genes, students create and draw an offspring. Then they complete a survey of some of their own dominant and recessive traits (freckles, widow's peak, length of second toe compared to first toe, handedness, tongue-rolling, and cleft chin). Finally, the class discusses how genetic problems might affect health.

Lesson 5: Sickle Cell Disease

The students reassemble the DNA models they made in Lesson 2 to better understand how genetic inheritance can produce variations in DNA. They receive a booklet entitled *Sickle Cell Trait and Sickle Cell Disease: An Activity Book* (available on request from UCSF Benioff Children's Hospital Oakland),[6] in which they draw a family tree and practice several Punnett squares showing how different types of sickle cell disease, sickle cell or other hemoglobin traits, or ordinary hemoglobin, can be inherited. A researcher or health care practitioner talks about current and future treatments for sickle disease, and a young adult affected by the disease speaks about living with it, showing how what the students have learned in class is reflected in real life. Students are encouraged to ask questions of the practitioner and young adult to help their understanding and break possible misconceptions.

The SEEK Curriculum

"Genetics and Sickle Cell Disease" is part of the 40-lesson SEEK curriculum, which was developed by UCSF Benioff Children's Hospital Oakland and includes eight instructional units, each of which teaches human biology and scientific investigation in the context of examining a disease or medical condition, such as sickle cell disease, which disproportionately affects racial and ethnic minorities. Other instructional units

Figure 1. Gene cards for "Plant Parenthood."

PLANT 1:	Front of card	Back of card
Flower color:	RED FLOWER	white flower
Seed shape:	ROUND SEED	ROUND SEED
Plant height:	TALL PLANT	short plant

PLANT 2:	Front of card	Back of card
Flower color:	RED FLOWER	white flower
Seed shape:	wrinkled seed	wrinkled seed
Plant height:	short plant	short plant

address obesity, traumatic brain injuries, infectious diseases, poisoning from environmental toxics, diabetes, asthma and lung disease, and heart disease.

The curriculum was designed with teacher input to make science interesting and relevant to students who come from racially and ethnically diverse, low-income environments; to help them meet state and national objectives for learning in health, science, and scientific inquiry; and to foster their interest in science, so that they may consider future careers related to biomedical science and thereby help eliminate disparities in the health care and biomedical research workforce. The curriculum objectives for student learning are:

1. Students will be able to carry out a simple scientific investigation.

The curriculum engages students in the scientific process and group problem solving, enabling them to use critical thinking skills. They practice observing, questioning, making predictions, hypothesizing, planning experiments, identifying and controlling variables, collecting data, measuring, estimating, making graphs, and drawing conclusions.

2. Students will be able to describe a variety of health care and biomedical science careers.

The curriculum uses role-playing and guest speakers to introduce careers. The lessons can be presented without guest speakers, but are enhanced by guests who can tell the students what they do in a typical day, what kind of training they needed, and what research is currently underway in their fields.

3. Students will be able to give examples of current topics of biomedical research.

Guest speakers provide information about current research. In addition, many of the experiments afford the opportunity to relate what the students are doing to cutting-edge research.

4. Students will report engaging in healthy behaviors such as eating more vegetables and exercising more often.

The lessons provide information on how to avoid many of the health conditions studied and give students the opportunity to role-play healthy behaviors. Some of the practical skills covered are hand washing, eating a balanced diet, getting plenty of exercise, not smoking, avoiding secondhand smoke, and drinking plenty of water.

5. Students will be able to define basic terms related to the human body such as "cell" and "artery" and will be able to explain the function of organs and organ systems such as "heart" and "immune system."

The curriculum takes a "learn by doing" approach to teach scientific concepts and terminology. Students learn through experiments, games, group problem solving, and other activities. Worksheets reinforce the lessons.

METHODS

Subjects

The Oakland Unified School District (OUSD), California, is a large, urban school district serving approximately 50,000 students, 94% of whom are non-white. At the time of this study (2006-2007 school year), scores on statewide tests revealed that only 39% of 5th grade students scored at the proficient or advanced level in math, and only 33% of 5th grade students scored at the proficient or advanced level in English/language arts.

The genetics unit was tested in a study involving 166 5th-grade students (50% male, 50% female) enrolled in OUSD schools. The experimental group consisted of 82 students at Fruitvale and Hoover Elementary Schools, the comparison group of 84 students at Allendale and Carl Munck Elementary Schools. The experimental and comparison schools were located in comparable socio-economic neighborhoods. The ethnicity of both groups was approximately 48% African American, 33% Latino, 12% Asian, 4% Caucasian, and 3% Pacific Islander.

Instruments

The SEEK staff and the program evaluator developed a 20-question, multiple-choice pre/posttest (see Figure 2) covering science concepts, scientific process, lifestyle choices, and careers related to genetics and sickle cell disease. Test-retest reliability was established by administering the pre/posttest to the comparison group (N=84) on two occasions 4 to 5 weeks apart. Percent agreement was 68.2%. This is low, but could be expected with elementary school students. Reliability of the test is further discussed below under "Limitations" and "Conclusion."

A sickle cell counselor who visited some of the classrooms gave 49 students information on sickle cell disease to take home to their parents along with a 5-question survey: 1. Did you receive materials about sickle cell disease and trait from your child this week? 2. Had you heard about sickle cell disease or trait before your child brought this information home to you? 3. Was your child born in California? 4. Do you know if you have been tested for sickle cell disease or trait? 5. What do you know about sickle cell disease and sickle cell trait? Questions 3 was included because all children born in California after Feb. 1990 have been automatically tested for sickle cell disease and trait.

Procedure

Students were administered the pretest a day or two before the first lesson was delivered, and the posttest within a week after the last lesson was delivered. Thus, 4 to 5 weeks elapsed between completion of the pretest and completion of the

Figure 2. Genetics pre/posttest.

Lesson Concepts

1. Genetics is ___________________________.
   a. a type of molecule
   b. the study of the patterns of inheritance of specific traits
   c. a contagious disease
   d. a type of diabetes

2. The cell is ___________________________.
   a. a recessive trait
   b. the basic unit and building block of life
   c. a DNA molecule
   d. all of the above

3. Every human cell contains ___________________.
   a. an organ b. a nucleus c. tissue d. ligaments

4. A healthy individual has _________ chromosomes.
   a. 42 b. 23 c. 46 d. 52

5. Genes are________________.
   a. a set of instructions for how your body looks and works
   b. your pants
   c. visible with a simple microscope
   d. RNA (ribonucleic acid)

6. What percent of your genes do you inherit from you mother?
   a. 50% b. 75% c. 100% d. 0%

7. Traits can be __________________.
   a. inherited from your parents
   b. learned
   c. harmful or helpful
   d. all of the above

8. DNA ____________________.
   a. looks like a twisted ladder
   b. can identify a person from a crime scene
   c. determines your traits
   d. all of the above

9. Where is DNA (deoxyribonucleic acid) located?
   a. in the nucleus of a cell
   b. in your heart
   c. in the food you eat
   d. none of the above

10. If I have a recessive trait, such as blue eyes, that means _________________.
    a. I inherited two recessive copies of the gene for the trait
    b. I inherited one recessive and one dominant copy of the gene for the trait
    c. I inherited no copies of the gene for the trait
    d. Both of the copies I inherited for that trait were dominant

11. Which of the following statements is correct?
    a. Dominant traits appear more often than recessive traits
    b. Some genes contain errors that cause genetic diseases
    c. You have two copies of each gene, one from your mother and one from your father
    d. all of the above

12. Which of the following is NOT inherited from your parents?
    a. eye color b. dimple(s) c. malnutrition
    d. sickle cell anemia

13. If I think that I might have a genetic disease, I should
    a. get tested and get my partner tested before we have kids
    b. take antibiotics
    c. be careful not to spread it to my friends
    d. change my DNA

14. Which of the following is a genetic disease?
    a. bronchitis b. West Nile Virus
    c. sickle cell anemia d. AIDS

15. Which of the following statements is NOT true about sickle cell anemia?
    a. It causes crescent (moon) shaped blood cells.
    b. It can be very painful if you have it.
    c. If you have it your red blood cells have trouble traveling properly though blood vessels.
    d. It is contagious. You can catch it like a cold.

Scientific Process

16. Scientific investigations involve_________________.
    a. hypotheses, tests, observations, and conclusions
    b. theories, guesses, and stories
    c. only variables and conclusions
    d. none of the above

17. I have two plants. The female plant has two copies of a dominant gene (BB) for big leaves. The male plant has two copies of a recessive gene (bb) for thin leaves. What genes do the offspring plants have, and what do they look like?
    a. BB (big leaves)
    b. Bb (big leaves)
    c. bb (thin leaves)
    d. CC (curly leaves)

18. You haven't done an experiment yet, but you think that African Americans have sickle cell anemia more often than other ethnic groups. This is your ____________________.
    a. hypothesis b. random variable
    c. conclusion d. control variable

Lifestyle

19. If I eat a healthy diet, exercise regularly and don't get too stressed, ________________
    a. I will be able to improve my genes
    b. I will have fewer recessive genes
    c. my genes won't change, but I will be making healthy lifestyle choices
    d. I will reduce my chances of having a genetic disease

Health Careers

20. Genetic counselors _________________________.
    a. screen for Down Syndrome
    b. do counseling for couples who have a family history of genetic disease
    c. interpret the results of genetic tests for couples who are planning to have children
    d. all of the above

posttest. Students in the comparison group also completed the two tests 4 to 5 weeks apart. The purpose of the comparison group was to determine whether the posttest results were affected either by having completed the pretest or by life and classroom experiences during a typical 4-to-5-week period.

Teachers received written instructions on the procedures for administering the tests so that the conditions were as similar as possible in each classroom. Teachers read each item aloud as the students read along. Students were allowed time to consider their answer choice if they needed it.

Data Analysis

Each of the 20 questions on the pre/posttests had one correct answer. Each incorrect answer was given a score of 0, and each correct answer a score of 1. The Statistical Package for the Social Sciences (SPSS) was used to analyze the data. A t-test was run on the overall test scores, as well as on each individual question.

RESULTS

The experimental group (Table 1) showed significant improvement on 13 questions ($P<.05$) and on the test as a whole ($P<.005$), whereas the comparison group (Table 2) did not show significant improvement either on any of the questions or on the test as a whole. The experimental students improved on 10 science concept questions, 2 scientific process questions, and 1 lifestyle question. Teachers rated the educational value of the unit as 9.5 on a scale from 1 (low) to 10 (high).

Posttest results show that after completing the 5 lessons, more students can correctly answer questions (#1, 3, 4, 5, 6, 9, 12, 13, 14, and 15) that use the following terms: genetics, nucleus, chromosome, gene, DNA, dominant gene, recessive

Table 1. Experimental group, pre/posttest results.

		Pretest					Posttest					t-test		
C	Q	Cor.	Inc.	N	M	SD	Cor.	Inc.	N	M	SD	t	df	P
0.29	1	44	38	82	0.54	0.50	68	14	82	0.83	0.38	-4.2	81	0.00
0.05	2	12	70	82	0.15	0.36	16	66	82	0.20	0.40	-.81	81	0.42
0.40	3	18	64	82	0.22	0.42	51	31	82	0.62	0.49	-5.8	81	0.00
0.36	4	23	58	81	0.28	0.45	52	29	81	0.64	0.48	-4.8	79	0.00
0.29	5	31	51	82	0.38	0.49	55	27	82	0.67	0.47	-3.0	81	0.00
0.35	6	45	35	80	0.56	0.50	74	7	81	0.91	0.28	-5.5	78	0.00
-.28	7	43	39	82	0.52	0.50	20	62	82	0.24	0.43	4.4	81	0.00
-.06	8	34	48	82	0.41	0.50	29	53	82	0.35	0.48	0.90	81	0.37
0.23	9	41	40	81	0.51	0.50	60	22	82	0.73	0.45	-3.8	80	0.00
0.10	10	26	56	82	0.32	0.47	34	48	82	0.41	0.50	-1.3	81	0.20
0.09	11	31	51	82	0.38	0.49	38	44	82	0.46	0.50	-1.4	81	0.18
0.34	12	27	54	81	0.33	0.47	55	27	82	0.67	0.47	-5.1	80	0.00
0.36	13	33	49	82	0.40	0.49	62	19	81	0.77	0.43	-5.8	80	0.00
0.56	14	24	56	80	0.30	0.46	70	11	81	0.86	0.34	-8.6	78	0.00
0.33	15	33	49	82	0.40	0.49	59	22	81	0.73	0.45	-4.3	80	0.00
-.09	16	57	25	82	0.70	0.46	50	32	82	0.61	0.49	1.35	81	0.18
0.15	17	33	49	82	0.40	0.49	45	37	82	0.55	0.50	-2.0	81	0.04
0.11	18	47	34	81	0.58	0.50	56	25	81	0.69	0.46	-2.0	79	0.05
0.21	19	44	38	82	0.54	0.50	61	21	82	0.74	0.44	-3.5	81	0.00
-.05	20	45	37	82	0.55	0.50	41	41	82	0.50	0.50	0.89	81	0.37
3.72	T	n/a	n/a	82	8.43	2.99	n/a	n/a	82	12.2	4.05	-9.7	81	0.00

C = Change
Q = Question number
Cor. = Correct
Inc. = Incorrect
N = Number of subjects
M = Mean
SD = Standard deviation
t = t value
df = Degrees of freedom
P = Significance
T = Total

Table 2. Comparison group, pre/posttest results.

		Pretest					Posttest					t-test		
C	Q	Cor.	Inc.	N	M	SD	Cor.	Inc.	N	M	SD	t	df	P
-.01	1	39	45	84	0.46	0.50	38	46	84	0.45	0.50	0.19	83	0.85
-.01	2	15	69	84	0.18	0.39	14	70	84	0.17	0.37	0.24	83	0.81
0.07	3	25	59	84	0.30	0.46	31	53	84	0.37	0.49	-1.2	83	0.22
-.04	4	33	50	83	0.40	0.49	29	52	81	0.36	0.48	0.54	79	0.59
0.02	5	28	55	83	0.34	0.48	30	54	84	0.36	0.48	-.34	82	0.73
-.03	6	53	31	84	0.63	0.49	50	33	83	0.60	0.49	0.45	82	0.66
-.05	7	45	39	84	0.54	0.50	40	43	83	0.48	0.50	1.09	82	0.28
0.01	8	36	48	84	0.43	0.50	36	47	83	0.43	0.50	0.00	82	1.00
-.03	9	38	46	84	0.45	0.50	35	48	83	0.42	0.50	0.36	82	0.72
-.05	10	23	61	84	0.27	0.45	19	65	84	0.23	0.42	0.73	83	0.47
-.17	11	38	46	84	0.45	0.50	24	60	84	0.29	0.45	2.75	83	0.01
0.01	12	23	60	83	0.28	0.45	23	57	80	0.29	0.46	-.22	78	0.83
-.11	13	45	39	84	0.54	0.50	36	48	84	0.43	0.50	1.69	83	0.09
-.16	14	28	54	82	0.34	0.48	15	67	82	0.18	0.39	2.25	79	0.03
0.00	15	22	62	84	0.26	0.44	22	61	83	0.27	0.44	0.00	82	1.00
-.11	16	46	36	82	0.56	0.50	38	46	84	0.45	0.50	2.18	81	0.03
0.02	17	32	52	84	0.38	0.40	34	50	84	0.40	0.49	-.39	83	0.70
0.04	18	40	43	83	0.48	0.50	43	39	82	0.52	0.50	-.85	80	0.40
-.01	19	39	45	84	0.46	0.50	38	46	84	0.45	0.50	0.20	83	0.84
-.01	20	43	41	84	0.51	0.50	42	42	84	0.50	0.50	0.18	83	0.85
-.64	T	n/a	n/a	84	8.23	3.14	n/a	n/a	84	7.58	3.54	1.90	83	0.06

C = Change; Inc. = Incorrect; SD = Standard deviation; P = Significance
Q = Question number; N = Number of subjects; t = t value; T = Total
Cor. = Correct; M = Mean; df = Degrees of freedom

gene, genetic disease, and sickle cell anemia. Also, more students can distinguish between hypotheses, variables, and conclusions (#18); know that lifestyle changes will not affect their genes (#19); and, given the genotypes of two parent plants, can correctly predict the genotype of the offspring (#17).

There was no difference between the experimental and comparison groups on defining "cell" (#2) or "recessive trait" (#10); recognizing three true statements about DNA (#8); or identifying activities of genetic counselors (#20). Comparison group performance declined significantly ($P<.05$) on recognizing three true statements about genetic inheritance (#11), and on identifying the components of scientific investigations (#16).

The only question on which the experimental group declined significantly was #7, which asked them to recognize three characteristics of traits: they can be inherited from your parents, can be learned, and can be harmful or helpful. Genetic traits, of course, cannot be learned. Since the rest of the test concerned only genetic traits, it was reasonable for the students to assume that this question, too, referred only to genetic traits. After completing the genetics unit, most of the students answered "can be inherited from your parents" or "can be harmful or helpful," both of which are indeed true statements about genetic traits. Thus, the students' answers actually do reflect learning, and this (inadvertently) was a trick question.

Ten parents returned the sickle cell survey, answering as follows: 1. Did you receive materials about sickle cell disease and trait from your child this week? (10 yes, 0 no) 2. Had you heard about sickle cell disease or trait before your child brought this information home to you? (7 yes, 3 no) 3. Was your child born in California? (9 yes, 1 no) 4. Do you know if you have been tested for sickle cell disease or trait? (6 yes, 4 no) 5. What do you know about sickle cell disease and sickle cell trait? On question #5, 5 parents gave correct statements, 2 left the question blank, and 3 gave other answers (they knew "nothing," they knew they had not been tested, or they wanted more information).

DISCUSSION

Limitations

Test-retest reliability was low (percent agreement = 68.2%) due to a trend of decline in scores of the comparison group. The sample for the sickle cell survey was too small to allow statistical analysis.

Conclusion

Pre/posttest results and student success with the activities show that 5th grade is not too early to teach genetics and cover sickle cell disease and (hemoglobin) trait(s). At this level, the groundwork can be laid for further study of genetics and genomics in middle school and high school. It appears that exposure to the pretest led to a general trend toward decline in scores of the comparison group (the decline in the overall score came close to significance, $P = .06$), indicating that exposure to the language of genetics and sickle cell disease, in the absence of appropriate instruction, might lead to misconceptions.

Although the sample for the sickle cell survey was small, the responses suggest that many families who might carry sickle cell trait have never even heard of it and do not know whether or not they have been tested. Questions 2 and 3 revealed that two parents (20% of those who responded) had never heard of sickle cell trait although their children had been born in California and therefore had been tested for it. In addition, parents who had some idea or had heard of sickle cell may have had partial or wrong information or none at all. These findings suggest the need for more genetics and sickle cell education at all levels.

As health care becomes progressively more individualized due to greater understanding of the human genome, it will become ever more important for people to understand genetic diseases, how genetics can influence non-genetic diseases, and how lifestyle choices can interact with genetics to influence health. This study shows that fifth grade is not too early to start laying the foundation for lifelong learning in these areas.

IMPLICATIONS

This study shows that genetics and concepts related to sickle cell disease can be successfully taught at the fifth grade level to racially and ethnically diverse students at a relatively low-performing school in a low-income neighborhood. These students may be at a higher risk for carrying sickle cell trait, but due to the cycle of poverty and inadequate education, many of their parents might not have heard of the sickle cell or other hemoglobin traits. Providing relevant education early has the potential for a long-term positive impact on public health.

HUMAN SUBJECTS APPROVAL STATEMENT

The Institutional Review Board (IRB) of UCSF Benioff Children's Hospital Oakland determined that this study met the qualification for Exemption pursuant to 45 CFR 46.101(1).

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