Nature or Nurture?
Heritability in the Middle School Classroom

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Overview:
From intelligence to laziness, artistic talent to how likely you are to become bald, people want to know, and debate about, whether traits are passed down from parents ("nature") or affected by environment ("nurture"). In reality, the question is not whether traits are passed to offspring, but rather how much nature and nurture affect particular traits. In this exercise, students will learn about the importance of nature *and* nurture in determining phenotypic differences among individuals by collecting data on themselves and their parents to estimate genetic heritability. With instructor guidance, students will decide to gather data on some traits that can be easily and reliably quantified (measured) for both themselves and their parents. Students will also develop their own predictions about how and why different traits have a higher probability of being "inherited" (either genetically or environmentally) as compared with other traits, as well as predict factors that could affect the estimates of genetic heritability.

Required Background Knowledge:
- Basic Mendelian genetics
- Materials in this online lecture (http://idea.ucr.edu/documents/flash/heritability_in_the_classroom/story.htm)

Lesson Concepts:
- Traits can be defined as any aspect of the phenotype that can be measured with a reasonable degree of accuracy and repeatability (e.g., student height or preference for sugary foods).
- The variation of any trait within a population (and within a sex or age class) is a result of both genetic differences among individuals ("nature") and the different environments each individual has experienced since conception (or even before), which is often referred to as "nurture."
- Environmental factors (e.g., diet) shared between parents and their offspring will tend to make them similar in appearance.
- If we compare parents with their offspring for a trait (e.g., height), we would generally expect to see a positive relationship because parents give both genes and aspects of the environment to their children.
- It is possible to separate the genetic and environmental aspects of "inheritance" when we compare human parents and their children, but doing so is complicated.

Objectives:
- Students will be able to predict relatively how closely parents and offspring should resemble each other for some different traits, considering both genetic and environmental sources of "inheritance."
- Students will be able to analyze the resemblance between parents and offspring by interpreting graphs.
- Students will be able to use appropriate discourse to debate the implications of nature and nurture in the development of offspring.

Grade Span: Middle school, 6-8

Materials:

- A computer with Internet connection and access to Google Forms/Sheets (may require creation of a free Google account).
- Teacher computer, connected to a projector if possible (if not, printouts and handouts of graphs created will be needed).
- Two options for inputting student data: (1) each student must be able to fill out the survey using Google Form individually (can be from a computer or smart phone); (2) teacher manually inputs data into Google Sheets for each student after completing the paper version of the survey.
- Supplies: white line paper, graph paper/grid paper for creating scatter plots, calculators, rulers

Advance Preparation:

1. Read Teacher Background (see below)
2. Follow instructions in Teacher Packet to create a Google Form if you choose this method to collect data
    - Instructions for analyzing data using the Google Sheets where the data will be collected and/or manually entered
    - Sample instructions for student report

Time: Three class periods (56 minutes each)

Grouping: Students will work individually, in groups of two or three, and participate in whole group discussion.

Teacher Background:

Variation in most phenotypic traits (e.g., height) within a population results from individuals having different genes (nature) **and** from individuals experiencing different environments, currently and as they grew up (nurture). This concept can be simply written as $V_P = V_G + V_E$, where V stands for variance (i.e., standard deviation squared) and P = phenotype, G = genotype, and E = environment. Most traits are controlled to some extent by genes, making them "heritable." However, heritability ranges between close to zero and as high as about 0.9 for some human traits. Heritability determines whether and how rapidly the average value of a trait for a population will change (evolve across generations) in response to natural, sexual or artificial selection. These concepts apply to both wild and domestic populations of sexually reproducing plants and animals, including human beings.

The term "heritability" can have several meanings, and is often used semi-colloquially. For purposes of this exercise, it is important to distinguish broad-sense from narrow-sense heritability. (Both of these are generally symbolized as "h^2" in the literature, which can lead to confusion.) Broad-sense heritability is the ratio of total genetic variance/phenotypic variance in a population. This includes non-additive effects of genes, i.e., dominance and epistasis. In general, dominance and epistasis do not contribute much to the resemblance between parents and their offspring because gene combinations are broken up when diploid parents produce haploid gametes (sperm and eggs). Broad-sense heritability is relevant for public policy because (by subtraction) it indicates how much of the variation in a population is environmental in origin, and hence potentially susceptible to manipulation in ways that would benefit human health or society (e.g., by educational or nutritional interventions).

Narrow-sense heritability is always lower than broad-sense heritability, as it equals the ratio of additive genetic variance/phenotypic variance for a given trait in a given population. This measure of heritability indicates, **on average**, how much of the variation in a trait is passed on from parents to their offspring within a specific population. Variances caused by genetic dominance and epistasis are not included in the calculation of narrow-sense heritability because they are not passed on from parents to their offspring. As additive effects of genes are, on average, faithfully passed down from parents to offspring, narrow-sense heritability is useful for predicting how rapidly a population will evolve over several or sometimes many generations. It is a main focus of animal and plant breeders, as well as evolutionary biologists.

All estimates of heritability apply to a particular trait, in given population, and at a certain point in time. Heritability often changes over time as the genetic composition of a population evolves and/or the environment changes. With very strong selection that continues for many generations, it is possible for narrow-sense heritability to be reduced to near-zero, as "good" alleles increase in frequency while "bad" alleles are eliminated from the population. Random mutations and gene flow from other populations would counter this process.

Narrow-sense heritability can be estimated as the slope of a regression of offspring on parents for a specific trait (assuming that you have no epistasis and also no non-genetic maternal or paternal effects and no common family environmental effects). In this exercise, the teacher instructs students to collect data on several traits that they find interesting and are easily measurable with a reasonable degree of accuracy (e.g., height, body mass, preference for sweets by self-assessment or see Possible Extensions). The teacher then performs regression analysis to estimate narrow-sense heritability for these traits.

Regression analyses are widely used for estimating relationships between variables. More specifically, regression analysis helps one understand how the typical value of the dependent variable changes when any one of the independent variables is varied, while the other independent variables are held fixed.

In this lesson plan, we have intentionally stayed mostly away from the term "heritability" because it is typically used by scientists to imply some degree of genetic heritability. With the data gathered and analyzed here, one could not entirely rule out the possibility that parent-offspring resemblance is completely environmental in origin.

Note: The study of heritability in human populations is complicated by various practical considerations. For example, with mice we can separate siblings at birth and raise them with different mothers or diets, but we cannot generally do that with people. However, scientists often do study twin registries maintained by state or national adoption agencies, and so sometimes can get information on twins (identical or not) that have been separated at birth. Identical twins raised together should be very similar, but identical twins raised apart should be less similar. These sorts of comparisons can allow the separation of genetic versus environmental effects on traits. Link to eventual IDEA lecture or Wikipedia page?

Note: Populations that have not yet fully admixed can give inflated heritability estimates. If the class is of diverse backgrounds (e.g., including some recent immigrant populations), then you may observe higher estimates than expected. Assortative mating can cause a similar upward bias in estimates of genetic heritability.

Key Vocabulary: behavior, characteristic, evolution, heritability, morphology, offspring, phenotype, physiology, population, trait, variable

Procedure:
Day 1: Background and Developing Predictions

1. **Prior to the Lesson (teacher prepares ahead of class time) -** Create a survey (on Google Forms or as a hard-copy handout) about 5 characteristics that you have pre-planned on your students measuring. [NOTE: Keep in mind how easy or difficult it will be to collect the data -- students will need to be in touch with their biological parents for information. Some good candidates for inclusion are skin color, preference for salty snacks, preference for sweet snacks, preference for sour foods, preference for coffee, frequency of exercise behavior.] [NOTE: Students who cannot get in touch with their biological parents can be given the option of entering "-9," a value traditionally used to indicate missing data. This should be explained at the beginning of class to relieve any possible student anxiety or potential embarrassment.] [NOTE: Keep in mind that data on characteristics such as height or shoe size may not reflect genetic heritability very well because middle school students are still growing, thus adding "noise" to the data. Using these characteristics could also be sensitive for students.]
   In Class-
2. **Warm Up/Do Now ("You Do")**:
   a. **Write** 5 characteristics down that you share in common with one or both of your biological parents. [NOTE: Explain that these traits can be morphological (e.g., skin color), physiological (e.g., blood pressure, diabetes) or behavioral (e.g., preference for spicy foods or classical music, a conservative political attitude). Put 5 characteristics you have in common with your parents on the board first as an example.] [**think** (5 minutes)]
   b. **Ask** students to share their list of common characteristics with their partner(s). [**pair** (5 minutes)]
   c. **Compile** a list of whole group characteristics on the white board- behavioral, morphological, and physiological. [NOTE: You could put three students in charge of each category or allow students to come up in small groups to write their characteristics on the board.] If you have repeated characteristics, place an X or √ next to the characteristic. [**share** (10 minutes)]
3. **Discussion**: Do these characteristics have anything in common? Which kinds of traits do you think are more likely to be shared between parents and children? Behavioral traits? Morphological traits? Physiological traits? Why would certain types of traits be more or less "shared" between parents and their offspring? Why do you think that? [NOTE: Get students to think about both genetic and environmental "inheritance."] [10 minutes]
4. **Discussion**: As a whole group, discuss which characteristics students might be interested in measuring. You should agree on 5 characteristics to make predictions for and then measure. Also discuss criteria for measurements (e.g. what counts as exercise?) [NOTE: You have already pre-selected the characteristics your students are going to be measuring.] [10 minutes]
5. **Predict/Discuss**: After selecting 5 characteristics, students should create and write predictions about which characteristics they expect to have the highest (strong resemblance to the average of their parents) and lowest heritability (low level of resemblance to parents) estimates, and have them explain their reasoning. For some traits, they may not expect any heritability. [10 minutes]
6. **Ticket to Leave (end-of-lesson wrap-up/assessment)**: How might the environment affect traits differently based on trait type (e.g., behavior vs. morphology)? [5 minutes] [NOTE: Either check the ticket to leave or have a short discussion before the class period ends.]

7. **Option 1: For homework, have students fill out the Google Form you have created** (see "Teacher Packet"). [NOTE: Be sensitive to the fact that some students may not want to provide this information, perhaps because they cannot contact or do not know one or both their biological parents. In that case, tell them to enter "-9" (without the quotations) for "missing values" in the Google Form.]
   Option 2: For homework, have students fill out the paper version of the survey you have created (see "Teacher Packet")**.** [NOTE: Be sensitive to the fact that some students may not want to provide this information, perhaps because they cannot contact or do not know one or both of their biological parents. In that case, tell them to enter "ND" (without the quotations) for "no data" in the survey.

Day 2 (Option 1 with Google Forms): Collecting Data/Reading, Interpreting, and Creating Graphs – See also this teacher packet, which has extensive instructions on the use of the Google Drive, Google Sheets for graphing, etc.
(http://idea.ucr.edu/documents/flash/heritability_in_the_classroom/Heritability_Exercise_Teacher_Packet_v10.pdf)

1. **Warm Up/Do Now**: What happens to heritability if parents and offspring had very different environments growing up? What if parents and offspring had very similar environments growing up? [think-pair-share (7-10 minutes)]
2. **Review** reading and interpreting the graphs. Why are offspring values on the y-axis (dependent variable)? Why are the parental values on the x-axis (independent variable)? What does one data point represent? What is a line of best fit? [10 minutes]
3. **Create** scatter plots with lines of best fit using individual class sets of data retrieved from Google Forms. Graphs are not being created using Google Sheets on Day 2. [NOTE: Parental values must be averaged before they can be plotted and it might be best to review creating a graph using one specific set of data before allowing students to do so individually.] [30 minutes]
4. **Ticket to Leave (assessment)**: Based on the individual class data you used today create graphs, do you think the traits you studied are heritable? Justify your answer. [5 minutes] [NOTE: Either check the ticket to leave or have a short discussion before the class period ends.]

Day 2 (Option 2 without Google Forms): Collecting Data/Reading, Interpreting, and Creating Graphs

1. **Warm Up/Do Now**: What happens to heritability if parents and offspring had very different environments growing up? What if parents and offspring had very similar environments growing up? [think-pair-share (7-10 minutes)]
2. **Compile** a list of whole group data using Google Sheets. *Data being entered for parents will need to be averaged before entering. **Option 1**: use your projector to display student data as you are entering into the spreadsheet. Students can check their data as you enter it. **Option 2**: if no projector is available allow each student to manually enter the data themselves. [NOTE: Convey to your students the importance of data quality and verification -- garbage in, garbage out!] [Length of time varies for this step depending on option choice.]
3. **Review** reading and interpreting the graphs. Why are offspring values on the y-axis (dependent variable; response variable)? Why are the parental values on the x-axis (independent variable; explanatory variable)? What does one data point represent? What is a line of best fit? [10 minutes]
4. **Create** scatter plots with lines of best fit using individual class sets of data. [NOTE: Parental values must be averaged before they can be plotted and it might be best to review creating a graph using one specific set of data before allowing students to do so individually.] [20 minutes]

5. **<u>Ticket to Leave (assessment)</u>**: Based on the individual class data you used today to create graphs, do you think the traits you studied are heritable? Justify your answer. [5 minutes] [NOTE: Either check the ticket to leave or have a short discussion before the class period ends.]

Day 3: Data Analysis and Interpreting Results

<u>Prior to the Lesson (teacher prepares ahead of class time)</u>-

1. **<u>Examine</u>** the student data and check for obvious errors in data entry. Remember to make a copy of the data file before you begin editing! [NOTE: Convey to your students the importance of data quality and verification -- garbage in, garbage out! In an advanced class, you may want to have students participate in the process of examining data.]
2. **<u>Create</u>** graphs (using all of your collected student data) and analyses directly in the Google spreadsheet where the data reside. [NOTE: See “Teacher Packet” if you need assistance using Google Sheets. You may also export the data to a graphics/statistical analysis program of your choice.] [NOTE: Watch for obvious biological "outliers" that might cause student discomfort or embarrassment (e.g., high body mass caused by obesity). Biological outliers (i.e., unusual data points that are not simply caused by measurement or typographic errors) can be good taking-off points for instruction (including the statistical complications they may cause). However, depending on the class, it may be prudent to delete them before showing the data. If so, then you may want to tell the class that the data have been edited by removing apparent outliers, which is common statistical practice.]

<u>In Class</u>-

3. **<u>Warm Up/Do Now</u>**: Using one of the graphs you (teacher) created using student data, either using the projector or as a handout, ask the following questions: **(1)** What trait are we analyzing? **(2)** Identify the x and y axis variables. **(3)** Could you put a line of best fit on this graph? Why or why not? [10 minutes]
4. **<u>Handout</u>**: Provide students with graphs and analysis results printouts which address student predictions.
5. **<u>Discussion</u>**: Were there any outliers (see also #1 and #3 above)? Go over the data collection process. Are outliers’ mistakes? How so? How do you deal with these problems? [10 minutes]
6. **<u>Reflection</u>**: Students will answer the following questions **individually** [15 minutes], followed by **whole group discussion** [10 minutes]: **(1)** Does the data support your predictions about heritability of traits? **(2)** Were any results surprising or unexpected? If so, how might you explain the results? **(3)** What do you think about the phrase “nature versus nurture” now that you have learned that most traits are affected by both genes and the environment? **(4)** List some other traits that could be studied.
7. **<u>Ticket to Leave (assessment)</u>**: How did you like this heritability exercise? What did you learn that you did not know previously? What would you like to see added or modified? [10 minutes] [NOTE: Students may share out their thoughts about the heritability exercise. Also have students complete this on a separate sheet of paper in order to collect and review the effectiveness of this exercise.]

Assessment:

- Warm Up/Do Now (quick check)
- Observation of student participation throughout the heritability exercise
- Completion of traits data collection (includes data entry into Google Sheets, via Google Form or manual entry by teacher)
- Ticket(s) to Leave (quick check)
- Reflection (found on Day 3)

Extension Activities

- Preference test for salty snacks: using several different kinds of potato chips with different amounts of sodium on the label, conduct a blind taste test in class. You can test for repeatability (consistency within individuals, tested at different times) by doing the same test a day or week apart. It might also be possible to get parents to do the same taste-test and let the students know their outcomes. [NOTE: You may not be able to find exactly the same snacks that differ only in salt content, so texture and other factors might be confounded. This could be a point for student discussion about proper scientific “controls.”]
- Preference test for brands of chewing gum: using several different brands of gum conduct a taste test in class. Students can decide which brand of gum they prefer for taste, consistency, ability to blow a bubble, etc.