Supplemental table 1: Pretest, post-test, and midpoint questions for the revisit condition

Identical items for both conditions *vs.* specified items for revisit condition	Questions in the unit
Identical for both conditions	Explore: Explain, in your own words, what is the difference between a gene and an allele?
Pretest (siblings): Identical for both conditions	Predict siblings traits: If you have siblings, you might look very similar to each other, but not exactly the same (unless you're an identical twin). Why do you think siblings look similar to each other, but not exactly the same?
Pretest (Punnett square): Identical for both conditions	Discover: Explain how you would use a Punnett square to figure out the probability of getting a certain genotype.
Identical for both conditions	Discover exercise: What is the probability that parents with genotype *Ee* and *ee* will have a child with attached earlobes?
Revisit condition	Distinguish: When the Punnett square is filled out, what do the four boxes represent? Explain how you would use a Punnett square to figure out the probability of getting a certain genotype.
Post-test (Punnett square): Identical for both conditions	Reflect on Punnett square ideas: Explain how you would use a Punnett square to figure out the probability of getting a certain genotype.
Revisit condition	Distinguish: How much DNA do you get from each of your parents? Select all answers that are true. (multiple choice)
Revisit condition	Distinguish: How could you use a Punnett square to explain why siblings look different from each other?
Post-test (siblings): Identical for both conditions	Reflect on siblings traits: If you have siblings, you might look very similar to each other, but not exactly the same (unless you're an identical twin). Why do you think siblings look similar to each other, but not exactly the same?

Supplemental table 2: Pretest, post-test, and midpoint questions for the critique condition

Identical items for both conditions *vs.* specified items for critique condition	Questions in the unit
Identical for both conditions	Explore: Explain, in your own words, what is the difference between a gene and an allele?
Pretest (siblings): Identical for both conditions	Predict siblings traits: If you have siblings, you might look very similar to each other, but not exactly the same (unless you're an identical twin). Why do you think siblings look similar to each other, but not exactly the same?
Pretest (Punnett square): Identical for both conditions	Discover: Explain how you would use a Punnett square to figure out the probability of getting a certain genotype.
Identical for both conditions	Discover exercise: What is the probability that parents with genotype *Ee* and *ee* will have a child with attached earlobes?
Critique condition	Distinguish: Student 1: "Two of their children will have free earlobes." Explain how this statement is incorrect or too vague, and how to make it more accurate.
Critique condition	Distinguish: Student 2: "Their fourth child will have attached earlobes." Explain how this statement is incorrect or too vague, and how to make it more accurate.
Post-test (Punnett square): Identical for both conditions	Reflect on Punnett square ideas: Explain how you would use a Punnett square to figure out the probability of getting a certain genotype.
Critique condition	Distinguish: Student 1: "Siblings get different amounts of DNA from each parent, so they don't look exactly the same." Explain how this statement is incorrect or too vague, and how to make it more accurate.
Critique condition	Distinguish: Student 2: "Some kids get genes from one parent, and some get their genes from the other parent." Explain how this statement is incorrect or too vague, and how to make it more accurate.
Post-test (siblings): Identical for both conditions	Reflect on siblings traits: If you have siblings, you might look very similar to each other, but not exactly the same (unless you're an identical twin). Why do you think siblings look similar to each other, but not exactly the same?

Supplemental table 3: Knowledge integration rubric for unit items

KI score	Description	Criteria	Examples from student responses
0	Blank response	-	-
1	Off task or I don't know	-	"I don't know."
2	Non-normative idea or links/irrelevant terminology use	1. Inheriting different amounts of DNA 2. Inheriting different sections of DNA 3. Inheriting different genes 4. Having different recessive and dominant genes 5. Age 6. Inherit more genes from one parent	**Siblings item:** "You inherit similar amounts of the same traits from the same parents at slightly different amounts. Because it's not exactly the same, you look a little different." **Punnett square item:** "It shows the possibility of one of the children getting one of the genes." **Critique item about genes** (fictitious student: Some kids get genes from one parent, and some get their genes from the other parent): "This is incorrect because all kids get more of their genes from their dad or mom. If you are a boy you get more of your genes from your dad and if you are a girl, your mom." **Critique item about DNA amount** (fictitious student: Siblings get different amounts of DNA from each parent, so they don't look exactly the same): "That is true since they get some of the same genes and some of different ones."
3	Partial link: one correct statement, but not connected to other scientific ideas, or student does not elaborate	1. Siblings inherit chromosomes/DNA from parents 2. Siblings get the same amount of DNA/genes from parents 3. Siblings have different alleles 4. Genotype: Siblings have different genotype 5. Siblings have same genes 6. Siblings have partially different DNA 7. Probability: Different possibilities on the Punnett square 8. Different genotype on Punnett square	**Exploring concepts:** "Allele is a different version of genes." **Punnett square item:** "It's like a multiplication table when you are doing expanded form. It shows the possibility of the child's traits." **Siblings item:** "You get a different set of genes than your sibling." **Critique item about genes** (fictitious student: Some kids get genes from one parent, and some get their genes from the other parent): "This statement is incorrect because children each get an equal amount of genes from their parents. Instead, they could've said that the children get genes from their parents but their traits may still vary." **Critique item about DNA amount** (fictitious student: Siblings get different amounts of DNA from each parent, so they don't look exactly the same): "A parent can not give more DNA to a child."
4	One valid link between normative scientific ideas	1. Inherit DNA or chromosome or gene from each parent + Half from each parent (50/50) 2. Chromosome has two copies of every gene + There are different versions of each gene 3. Half of DNA/chromosome/gene from each parent + Different alleles (no elaboration) 4. Half of DNA or chromosome or gene from each parent + Probability (no elaboration) 5. Different combination of alleles 6. Same chance of getting a certain phenotype 7. Example: 50/50 in Punnett square means 50% percent chance blue eyes and 50% chance of something else	**Exploring concepts:** "An allele is a version of a gene, a gene is a piece of DNA." **Siblings item:** "Because you get half of your parents DNA but it does not specify which half you will inherit from them. This means that the half that you might get will not be the same that your sibling will get." **Punnett square item:** "To figure out the probability of a Punnett square to find a certain genotype, you can see what genotype your parent's alleles have and with both of them you can see the probability you will get from your parents." **Critique item about genes** (fictitious student: Some kids get genes from one parent, and some get their genes from the other parent): "Kids get 50% of their genes from one parent and 50% from the other the parents alleles make the look." **Critique item about DNA amount** (fictitious student: Siblings get different amounts of DNA from each parent, so they don't look exactly the same): "It isn't the fact that they get different amounts but because they could get different types of alleles that define different traits."
5	At least two valid links	1. Siblings inherit half of genes/chromosomes/DNA from one parent and the other half of genes/chromosomes/DNA from the other parent + Siblings randomly get different combinations of genotype or alleles from their parents' genotype 2. Each chromosome has two copies of every gene. There are different versions of each gene, called alleles. Alleles can either be dominant or recessive + Siblings randomly get different combinations of genotype or alleles from their parents' genotype + Probability	**Exploring concepts:** "A gene is a short piece of DNA that codes for something. Genes determine your traits, such as eye color and hair color. You may also notice that the chromosomes are all in pairs. That means you can have different versions of each gene, called alleles." **Siblings item:** "Siblings do not look exactly the same because they have slightly different alleles. Each child has a chance of receiving a different allele from its parents than its sibling because of probability." **Punnett square item:** "The Punnett square shows all the different combinations of alleles the offspring could get when you enter the genotype of the parents, so I would enter the parents' genotype. Then, I would find the genotype I want to calculate the probability." **Critique item about genes** (fictitious student: Some kids get genes from one parent, and some get their genes from the other parent): "This statement is incorrect because you get one copy of each gene from both of your parents and those copies combine together to make your gene versions and the phenotype." **Critique item about DNA amount** (fictitious student: Siblings get different amounts of DNA from each parent, so they don't look exactly the same): During sexual reproduction, each parent randomly passes on one copy of their genes, so the siblings couldn't have gotten different amount of DNA, but may have gotten different combinations of genotype or alleles from their parents' genotype.

KI: knowledge integration.

Supplemental table 4: Short answer and multiple-choice rubric for embedded items

Score	Description	Examples from student responses
0	Incorrect	Exercise Punnett square (What is the probability that parents with genotype *Ee* and *ee* will have a child with attached earlobes?): "The possibility of them having kids with the attached earlobes with *Ee* and *ee* is two kids." Critique item about quantity of offspring in Punnett square (fictitious student: Two of their children will have free earlobes.): "Three of the children will have free earlobes." Critique item about order of offspring in Punnett square (fictitious student: Their fourth child will have attached earlobes): "That is incorrect because the fourth child has *ee* meaning they will get attached earlobes." Revisit Multiple Choice about DNA (How much DNA do you get from each of your parents?): "More from one parent, depending on which parent you look more like."
1	Correct	Exercise Punnett square (What is the probability that parents with genotype *Ee* and *ee* will have a child with attached earlobes?): "It would be 50% because one of them starts with *E* and the other starts with *e*". Critique item about quantity of offspring in Punnett square (fictitious student: Two of their children will have free earlobes.): "The probability is 3/4 or 75% that their children can have free earlobes. So it could be that only 1 of their children. So each child has a probability of 3/4 of having free earlobes." Critique item about order of offspring in Punnett square (fictitious student: Their fourth child will have attached earlobes): "The first child or 2nd or 3rd could have attached earlobes. To make it more accurate, you could say that each child has a 1/4 probability of having attached earlobes." Revisit Multiple Choice about DNA (How much DNA do you get from each of your parents?): "You get an equal amount from both parents, half from each., One of each pair of chromosomes from each parent."