Design-o-saurs: Using Inquiry to Reinforce Aspects of the Relationship between Genotype & Phenotype

NABT BioClub RECOMMENDATION

STEVEN M. AUTIERI

Abstract

Biological concepts such as transcription, translation, codons, and genes can be confusing and overwhelming to high school biology students, yet these are prominent topics assessed on high-stakes standardized tests. I present a project-based assessment approach that can help students organize the wealth of information covered during units on genetics and protein synthesis. Students create a three-dimensional "Design-o-saur" model based on the genetic sequences of parent dinosaurs that they have already transcribed and translated to determine the proteins responsible for the observable traits. Ready-to-use handouts, evaluation rubrics, and student guidelines are included.

Key Words: *Biological sciences; central dogma; inquiry; assessment.*

○ Introduction

The amount of content introduced to high school biology students during units on genetics and protein synthesis can be daunting for them to organize in their mental filing cabinets. Students often ask, "Why is this important to me?" This question alone illustrates the challenge for educators to create authentic, application-based approaches that permit students to do more than simply memorize terminology for use on a factual-recall assessment. "Situated learning," which relies largely on the contexts in which the learning takes place, is not enough. Students can truly demonstrate comprehension of the subject matter only when learning is situated in real-world activities (Koch, 2009).

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The use of evaluation rubrics structured to the assessment instrument is also a significant component of authentic assessment. By providing students with rubrics, we inform them of the expectations and assessment criteria for their work before they begin the assignment. These types of assessment tools also provide crucial opportunities for self and peer assessment to occur (Nowak & Plucker, 2002). Lesson activities must also be closely aligned to the *Next Generation Science Standards* (NGSS) Science and Engineering Practices. Engaging in these practices allows students to develop scientific literacy while making the knowledge more meaningful and closely related to the real world (NGSS Lead States, 2013, appendix F).

The learning task presented here is targeted to address the development of concepts critical to understanding the "central dogma." The particular assessment strategy consists of two parts that will eventually entail the construction of a "Design-o-saur" model in which students decode "dinosaur DNA" from two homologous chromosomes, transcribe it to mRNA, and, utilizing tRNA, complete the translation to form several different amino acid sequences representing several enzymes responsible for observable traits. It is critical to emphasize to students that tRNA is complementary to the mRNA codons and is responsible for the pairing of a codon to its amino acid, but that it is the codon that allows them to determine the amino acid from the codon table (genetic code). In the second phase of the project, students utilize gametes created during part 1 to combine genetic information to create offspring. Students build a three-dimensional model of their offspring dinosaur, accurately depicting phenotypes. This is a suitable project for either block schedules of 90 minutes or 45-minute class periods. It was designed to be ready for implementation along with graphic organizers and evaluation rubrics and is aligned with the *National Science Education Standards* for science content and teaching (National Research Council, 1996; Table 1).

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Table 1. Addressing the standards.

National Science Education Standards (National Research Council, 1996) for teaching that are addressed during this activity	*Next Generation Science Standards* (NGSS Lead States, 2013) for content matter that are addressed during this activity
Teaching Standard A: Planning Inquiry-Based Science Programs. • Select teaching and assessment strategies that support the development of student understanding and nurture a community of science learners. (p. 30)	**HS-LS1-1.** Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.
Teaching Standard B: Teachers of Science Guide and Facilitate Learning. • Focus and support inquiries while interacting with students. (p. 33)	**HS-LS3-1.** Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.
Teaching Standard C: Teachers of Science Engage in Ongoing Assessment. • Use multiple methods and systematically gather data about student understanding and ability. (p. 38) • Guide students in self-assessment. (p. 42)	

○ Essential Questions

This lesson is driven by several guiding questions that students should be able to answer by the conclusion of the lesson elements:

1. Explain how codons found in DNA are used to build RNA and finally to build proteins.
2. What is the triplet code and how does it code for the amino acids in proteins?
3. Explain how RNA is produced during transcription.
4. Describe the role of mRNA, rRNA (ribosomes), and tRNA during the process of translation.
5. Analyze how mutations or changes in the sequence of DNA can lead to changes in the proteins produced.

○ Engage the Learner: Day 1

The first phase of the learning process captures students' interest and helps them make connections with what they know and can do, while permitting the teacher to gauge prior knowledge and alternative conceptions. In this particular phase, I have found it useful for students to conduct a card-sort activity in small teams to review and reinforce key vocabulary pertinent to the completion of the major exploration activity in the lesson. The teacher places vocabulary terms and their respective definitions on cards that students will match together. Relevant vocabulary includes the following: homologous chromosomes, diploid, haploid, gamete, allele, genotype, phenotype, homozygous, heterozygous, dominant, recessive, and incomplete dominance (Figure 1).

○ Explore the Concept: Days 1–3

In this phase, students are provided opportunities to explore the content through active, hands-on activities. First, the teacher should assign each student the "mother" or "father" chromosomes to represent the DNA of their parent dinosaur (duplications among students

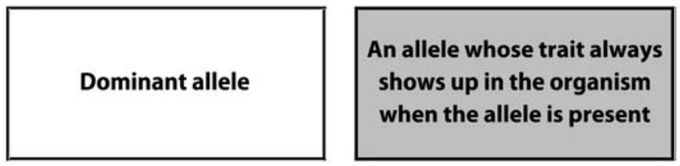

Figure 1. Sample vocabulary-concept sort-activity cards.

in the class is fine). Teachers in my department have often placed slips of paper with the sexes written on them in a paper bag and had students randomly select the sex of their parent dinosaur. Once the selection has been made, students retrieve two copies of the parent *DNA sequence organizer*, representing chromosomes A and B (Figure 2). The worksheets provide the DNA sequence for each of the homologous chromosomes but require that students first transcribe the mRNA message and then the tRNA anticodons that are complementary to the bases on the mRNA strand.

Now that the students have the information needed to translate their RNA sequence into an amino acid sequence, the teacher can distribute the *amino acid sequence for traits* (Figure 3) and the *mRNA codon wheel* (Figure 4) so that the students can determine the phenotypic traits represented by the 10 genes depicted on each homologous chromosome. It is critical that the teacher provide scaffolding through questioning at each of these steps, because some students may still struggle with transcribing and translating genes.

After completing sequences on the DNA sequence organizer, students will receive two enlarged chromosome diagrams and a chart for the genotypes and phenotypes of their parent dinosaur (Figure 5).

○ Instructional Considerations

Teachers in my department are particularly fond of this part of the project because it provides students a chance to integrate prior knowledge into the exercise by revisiting terminology such as *genotype* versus *phenotype* and *dominant* versus *recessive* traits. Children benefit most from authentic assessment when they are allowed to

DNA	TAC	CAA	ACC	ACG	CCA	ATC	TAC	TAT	GGC	CGA	GTG	ATT	TAC	GCT	TAG	TTT	GTG	ATC	TAC	TTC
mRNA																				
tRNA																				
AMINO ACID																				
GENE																				

DNA	GGG	AAA	CTT	ATC	TAC	AAT	TGG	AGT	CCA	ATC	TAC	CTT	TCT	GGG	ACC	ATT	TAC	CGA	CTA	CCA
mRNA																				
tRNA																				
AMINO ACID																				
GENE																				

DNA	CAC	ATT	TAC	ATA	ACG	AAG	TTT	ATT	TAC	AAA	AGA	CTA	TTT	ATT	TAC	GTT	ATA	TAT	GCC	ATT
mRNA																				
tRNA																				
AMINO ACID																				
GENE																				

DNA	TAC	CAA	ACC	ACG	CCA	ATC	TAC	TAT	GGC	CGA	GTG	ATT	TAC	GCT	TAG	TTT	GTG	ATC	TAC	TTC
mRNA																				
tRNA																				
AMINO ACID																				
GENE																				

DNA	GGG	AAA	CTT	ATC	TAC	AAT	TGG	AGT	CCA	ATC	TAC	CTT	TCT	GGG	ACC	ATT	TAC	CGA	CTA	CCA
mRNA																				
tRNA																				
AMINO ACID																				
GENE																				

DNA	CAC	ATT	TAC	ATA	ACG	AAG	TTT	ATT	TAC	AAA	AGA	CTA	TTT	ATT	TAC	GTT	ATA	TAT	GCC	ATT
mRNA																				
tRNA																				
AMINO ACID																				
GENE																				

Figure 2. DNA sequence organizer.

Gene 1: **Blue:** Methionine, Valine, Tryptophan, Cysteine, Glycine
Yellow: Methionine, Valine, Tryptophan, Cysteine, Glutamine

Gene 2: **Carnivorous:** Methionine, Isoleucine, Proline, Alanine, Histidine
Herbivorous: Methionine, Isoleucine, Serine, Alanine, Histidine

Gene 3: **Horns:** Methionine, Histidine, Isoleucine, Lysine, Histidine
No Horns: Methionine, Arginine, Isoleucine, Lysine, Histidine

Gene 4: **Spikes:** Methionine, Lysine, Proline, Phenylalanine, Glutamic Acid
No Spikes: Methionine, Lysine, Proline, Phenylalanine, Threonine

Gene 5: **Big Body:** Methionine, Leucine, Threonine, Serine, Glycine
Small Body: Methionine, Leucine, Threonine, Phenylalanine, Glycine

Gene 6: **Quadruped:** Methionine, Glutamic Acid, Arginine, Threonine, Serine
Biped: Methionine, Glutamic Acid, Arginine, Proline, Tryptophan

Gene 7: **Long Neck:** Methionine, Alanine, Aspartic Acid, Glycine, Valine
Short Neck: Methionine, Serine, Isoleucine, Glycine, Valine

Gene 8: **Claws:** Methionine, Tyrosine, Cysteine, Phenylalanine, Lysine
No Claws: Methionine, Tyrosine, Histidine, Phenylalanine, Lysine

Gene 9: **2 Pair Wings:** Methionine, Phenylalanine, Serine, Aspartic Acid, Valine
No Wings: Methionine, Phenylalanine, Serine, Aspartic Acid, Lysine

Gene 10: **Brown Eyes:** Methionine, Glutamine, Tryptophan, Isoleucine, Arginine
Blue Eyes: Methionine, Glutamine, Tyrosine, Isoleucine, Arginine

Figure 3. Amino acid sequence for traits.

build upon their prior experiences and knowledge (Lehrer et al., 2000). Students will also require the supplement "How Genes Are Expressed" (Figure 6) to understand whether the various traits are

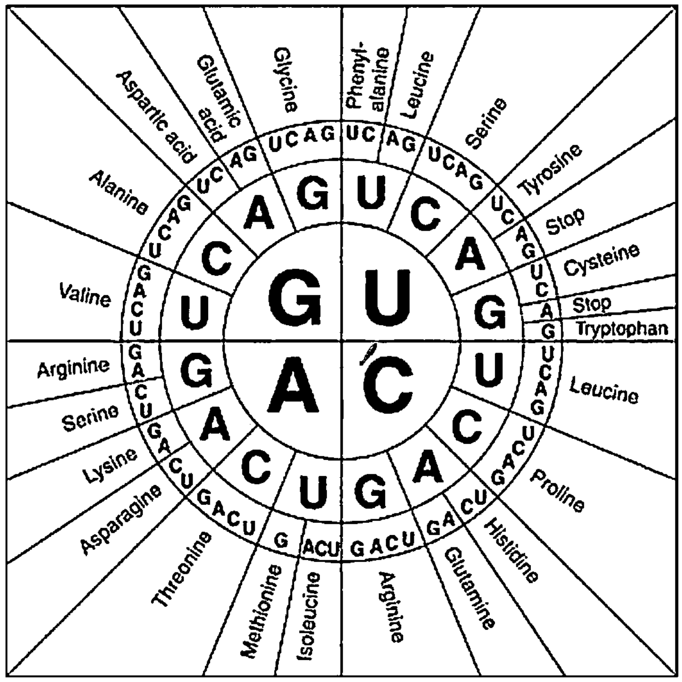

Figure 4. Codon wheel (http://local.brookings.k12.sd.us/biology/images/BIO%20I%201.gif).

expressed dominantly, recessively, or incompletely. The teacher should emphasize that incomplete dominance implies that neither allele is completely dominant and that the offspring will have a phenotype somewhere between those of the parents. The teacher should also emphasize that while presenting them this way is convenient for our purposes, the DNA sequences of the genes are never next to each other; they are often on different chromosomes or are separated by noncoding, intervening sequences (introns) that are modified in the pre-mRNA before translation takes place.

The case-sensitive letters corresponding to each gene will be written on each line of chromosome, indicating whether the gene is dominant or recessive. For example, if the students found the first gene to represent a yellow phenotype for body color, the chart indicates that this is the recessive form of the gene and is thus represented by a lowercase "b". Students will combine the same genes from each homologous chromosome to determine the phenotype and genotype of the parent dinosaur. For instance, if chromosome A had a "B" for body color and chromosome B had a "b" for body color, the parent genotype would be recorded as "Bb" and thus would represent a phenotype of green.

○ Explain & Evaluate: Student Understanding of the Concept

In this phase of the learning process, the students utilize the key vocabulary terms to explain what they have experienced during the exploration phase. The students also try to make connections between this knowledge and what they have already learned. At this point, before transitioning into the final phase of the project, it's a good idea to collect formative assessment data. Students now communicate the results of their gene-to-protein decoding by synthesizing a diagram of the parent dinosaur that depicts all 10 traits with

DNA Sequence: Mother Chromosome A

DNA	TAC	CAA	ACC	ACG	CCA	ATC	TAC	TAT	GGC	CGA	GTG	ATT	TAC	GCT	TAG	TTT	GTG	ATC	TAC	TTC
mRNA																				
tRNA																				
AMINO ACID																				
GENE																				

DNA	GGG	AAA	CTT	ATC	TAC	AAT	TGG	AGT	CCA	ATC	TAC	CTT	TCT	GGG	ACC	ATT	TAC	CGA	CTA	CCA
mRNA																				
tRNA																				
AMINO ACID																				
GENE																				

DNA	CAC	ATT	TAC	ATA	ACG	AAG	TTT	ATT	TAC	AAA	AGA	CTA	TTT	ATT	TAC	GTT	ATA	TAT	GCC	ATT
mRNA																				
tRNA																				
AMINO ACID																				
GENE																				

DNA Sequence: Mother Chromosome B

DNA	TAC	CAA	ACC	ACG	CCA	ATC	TAC	TAT	GGC	CGA	GTG	ATT	TAC	GCT	TAG	TTT	GTG	ATC	TAC	TTC
mRNA																				
tRNA																				
AMINO ACID																				
GENE																				

DNA	GGG	AAA	CTT	ATC	TAC	AAT	TGG	AGT	CCA	ATC	TAC	CTT	TCT	GGG	ACC	ATT	TAC	CGA	CTA	CCA
mRNA																				
tRNA																				
AMINO ACID																				
GENE																				

DNA	CAC	ATT	TAC	ATA	ACG	AAG	TTT	ATT	TAC	AAA	AGA	CTA	TTT	ATT	TAC	GTT	ATA	TAT	GCC	ATT
mRNA																				
tRNA																				
AMINO ACID																				
GENE																				

DNA Sequence: Father Chromosome A

DNA	TAC	CAA	ACC	ACG	CCA	ATC	TAC	TAT	GGC	CGA	GTG	ATT	TAC	GTA	TAG	TTT	GTG	ATC	TAC	TTC
mRNA																				
tRNA																				
AMINO ACID																				
GENE																				

DNA	GGG	AAA	TGA	ATC	TAC	AAT	TGG	AGT	CCA	ATC	TAC	CTT	TCT	TGG	AGA	ATT	TAC	AGC	TAG	CCA
mRNA																				
tRNA																				
AMINO ACID																				
GENE																				

DNA	CAC	ATT	TAC	ATA	ACG	AAG	TTT	ATT	TAC	AAA	AGA	CTA	CAC	ATT	TAC	GTT	ACC	TAT	GCC	ATT
mRNA																				
tRNA																				
AMINO ACID																				
GENE																				

DNA Sequence: Father Chromosome B

DNA	TAC	CAA	ACC	ACG	GTC	ATC	TAC	TAT	GGC	CGA	GTG	ATT	TAC	GCT	TAG	TTT	GTG	ATC	TAC	TTC
mRNA																				
tRNA																				
AMINO ACID																				
GENE																				

DNA	GGG	AAA	TGA	ATC	TAC	AAT	TGG	AAA	CCA	ATC	TAC	CTT	TCT	TGG	AGA	ATT	TAC	AGC	TAG	CCA
mRNA																				
tRNA																				
AMINO ACID																				
GENE																				

DNA	CAC	ATT	TAC	ATA	ACG	AAG	TTT	ATT	TAC	AAA	AGA	CTA	CAC	ATT	TAC	GTT	ACC	TAT	GCC	ATT
mRNA																				
tRNA																				
AMINO ACID																				
GENE																				

Figure 5. Chromosome diagrams.

Dominant	Recessive	Incomplete Dominance
(B) Blue body	(b) Yellow body	(BY) Green body
(C) Carnivore	(c) Herbivore	
(H) Horns	(h) No horns	
(S) Spikes	(s) No spikes	
(D) Big body: 6 inches from ground to shoulder or taller	(d) Little body: 4inches from ground to shoulder or shorter	
(Q) Quadruped (hind legs longer than front legs/arms)	(q) Biped (walks on two legs; has small arms)	(QB) Triped (walks on three legs); offspring usually killed by prey early in life
(N) Long neck; ½ length of the body (including a tail) or longer	(n) Short neck; ⅓ length of the body (including a tail) or shorter	
(A) Claws	(a) No claws	
(W) Two pairs of wings	(w) No wings	(WN) One pair of wings
(B) Brown eyes	(b) Blue eyes	(BG) Green eyes

Figure 6. How Genes Are Expressed.

sufficent accuracy (Figure 7). Evaluation is based on a rubric (see Appendix) in which the student submits an entire packet including the sequence charts and dinosaur diagram. Students will have the opportunity to engage in NGSS content standard HS-LS3-1 as they complete the diagram component of this lesson phase: they will be able to visualize the role that DNA provides in yielding the traits and their corresponding phenotypes after transcription and translation have taken place. This will give the teacher insight on any content matter that needs to be reemphasized or any alternative conceptions that need to be addressed before moving to the next phase of the project.

○ Writing to Communicate

For formative assessment of student learning, students are asked to develop their critical-thinking and communication skills through the completion of writing prompts. Students will be permitted and encouraged to utilize course resources to support and defend their responses. The use of a writing assignment at this stage will help uncover any alternative conceptions still present among the students. The teacher can also use the assignment to work with struggling writers. Sample prompts at the conclusion of part 1 of the assignment could be

> *Suppose you knew the makeup of specific proteins in a cell. How would you determine the particular DNA code that coded for them? Provide examples to support your reasoning.*

or

> *How could one change in a DNA nucleotide alter the formation of the translated protein?* (An example would be the difference between normal and sickle-cell hemoglobin.)

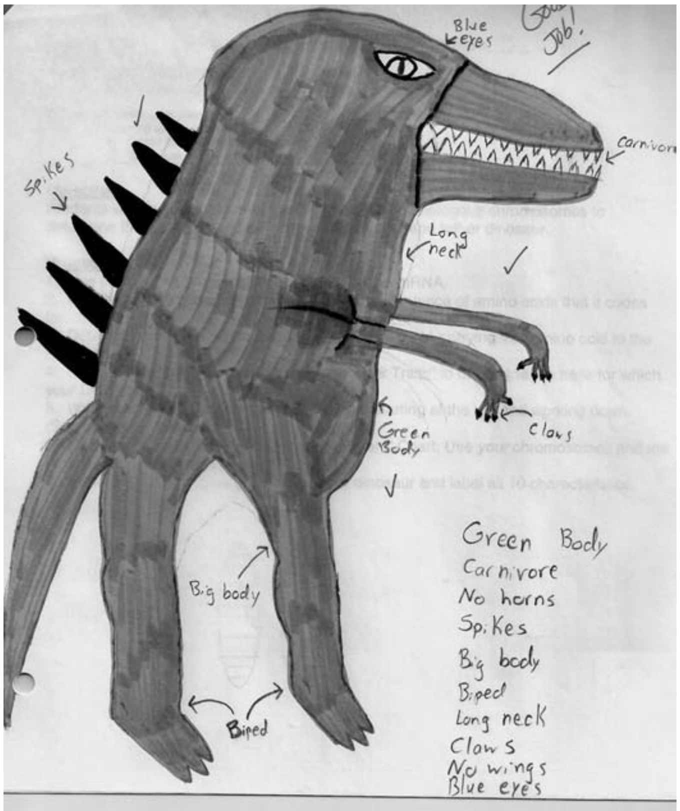

Figure 7. Sample student diagram of parent dinosaur depicting 10 phenotypic traits.

The NGSS, especially practice number 8, emphasize the need for students to read and interpret scientific text while developing key communication and writing skills. Students will need to communicate scientific information in the responses to the prompts above to clearly persuade the reader to support their viewpoints.

○ Exploration Part 2: The Origins of Life (about 1–2 class periods)

The objective for the second part of the project is to provide students the ability to produce an offspring dinosaur by the combining of gametes during sexual reproduction. Students also have the opportunity to build on the prior knowledge of genetic principles such as the passage of genes from parent to offspring and the law of segregation. Just as students filled in the parental chromosomes from part 1 with the 10 different genes, they also completed a second set of homologous chromosomes from their parent to be used in part 2.

As students enter class on the first day of this second part of the exercise, the teacher points out two glass mason jars in the front of the room, one labeled “EGGS” and the other labeled “SPERM.” Students are given a few minutes to cut out their chromosome copies with scissors, fold them in half, and place them into the appropriate jar. I have often added additional gametes to the jars to increase variety and inform students that this happened because some new dinosaurs have joined the herd. This is a great time for the teacher to remind students of critical genetics concepts, such as the fact that

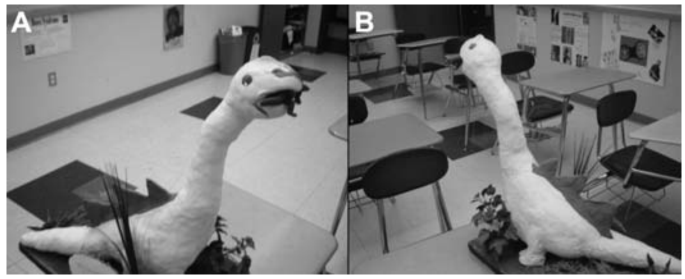

Figure 8. Sample student three-dimensional model of offspring dinosaur created with papier-mâché.

sexually reproducing organisms with two copies of a gene will have those genes segregated when forming offspring. Teachers can also use this as an opportunity for formative assessment by higher-order questioning. The use of open-ended questions promotes science as a way of doing and encourages activity while constructing knowledge.

One by one, students next select one chromosome from each jar to determine the genetic makeup of their offspring dinosaur. Each student will now possess two new paper chromosomes that they will staple into their packets following the guidelines for part 2. The students will then record the genotypes and phenotypes for each gene, already determined in part 1, in the “Genotype and Phenotype Chart” (Figure 5).

○ Welcome Little One! (~1 week)

Next, students create a diagram representing the phenotypic characteristics of their offspring dinosaur. In our department, this has been the only phase of the project treated as an out-of-class assignment. Students also have the opportunity to construct a three-dimensional model of their baby dinosaur for extra credit. Students can be as imaginative and creative as possible, having the freedom to select everything from the dimensions of the model to the materials used to build it. I have seen my students use a variety of materials, from papier-mâché to modeling clay. Several students have built their dinosaurs as part of a diorama scene (Figure 8). The construction of the dinosaur models or diagrams aligns nicely with NGSS Science and Engineering Practice 2 on developing and using models. Students use these models to represent evidence obtained as to how DNA codes for specific traits of an organism. Although production of the model takes a significant amount of time, there is an instructional implication for specific subgroups of learners. In order to maximize student learning in the classroom, teachers must provide a diverse array of opportunities to meet all learning styles. For instance, the literature has depicted a strong correlation between kinesthetic learning opportunities and language development for struggling English-language learners (Wintergerst et al., 2003; Mulalic et al., 2009).

○ Extending & Evaluating the Learning (~1 week)

In the final phase of the learning cycle, students are given opportunities to apply the concepts and ideas from the previous phases to a novel context. As a way for students to demonstrate a strong conceptual understanding of the central dogma, I challenge them to create a multimedia presentation of a process in a biological organism that relies on successful protein synthesis.

For example, students have created digital posters demonstrating the process of how the *Luc* gene is transcribed and translated to produce the luciferase enzyme that fireflies use to glow. Students have also chosen to examine the products of defective enzymes, such as the one that leads to the defective pigment molecules of albinism. Students are given the choice to produce a critical work product such as a Prezi presentation, digital movie, storybook, or digital poster to showcase their research. This activity promotes student practice with regards to NGSS Science and Engineering Practice 6: they construct explanations about their selected biological process, utilizing valid and reliable textual and digital resources.

Students will need to be familiar with the functionality of their selected process before they can create an explanation to present to their peers. They will need to connect their previous learning of the central dogma to demonstrate how the DNA blueprint eventually codes for functional proteins in the cells of living organisms (NGSS content standard HS-LS1-1).

○ Differentiation for Subgroups of Learners

The activity can be modified to assist lower-level students in a few different ways. The teacher could provide the DNA-sequence worksheets partially completed to provide examples to the students. This would also assist the teacher in modeling completion of the worksheet to the students. Although this activity will work well on an individual basis, students could be flexibly grouped to match struggling students with on-level students. For exceptional learners, a RAFT (role, audience, format, topic) writing prompt could be assigned. The RAFT strategy allows students to understand the role they will have as a writer, the audience they will address, the formats available for writing, and the topic of content. The format of RAFTs makes them easy to differentiate, and the teacher could develop several different styles of RAFTs based on the ability and rigor levels in their classroom. RAFTs allow students to demonstrate mastery of the content by providing options for communicating their knowledge. The RAFT strategy has been proven to assist students in making connections between new and prior knowledge as they develop literacy skills, as well as taking the traditional essay and orienting it toward a more free-style, creative format (Topping & McManus, 2002; Groenke & Puckett, 2006). Students will apply relevant terminology (genotype, phenotype, dominance, DNA, genes) through the RAFT essay.

As a society, we need to develop scientifically literate citizens who have the communication and problem-solving skills necessary to tackle critical societal issues such as global warming and stem cell research. Providing authentic student work products and assessments in our classrooms that are faithful to real-world contexts ensures that students build the skills necessary to compete in the 21st century. As Richard Light (2001) stated in his book *Making the Most of College: Students Speak Their Minds*, "Students improve and are engaged when they receive feedback (and opportunities to use it) on realistic tasks requiring transfer at the heart of learning goals and real-world demands."

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STEVEN M. AUTIERI is a science teacher in the Academy for Technology and Academics, Conway, SC 29526. E-mail: smautieri@gmail.com.

Appendix Supplemental Worksheet: Student Project Handouts/Evaluation Rubrics

Part 1: What Does the Parent Look Like?

Name:___________________________**Teacher**______________**Period**______

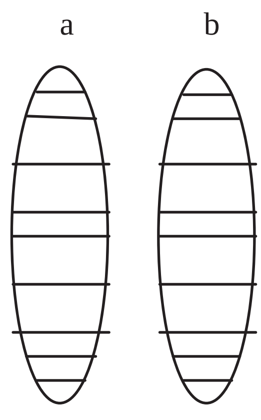
> ### 21st-Century Skills Demonstrated:
> - Learning and Innovation Skills
>   1. Critical thinking and problem solving
>   2. Communication and collaboration

Objective

Students will be able to decode the DNA from two homologous chromosomes to determine the genotype and phenotype of a mother and father dinosaur.

Procedure

1. Using the parent DNA sequence provided to you, transcribe the mRNA. Be sure that you are utilizing appropriate base-pairing rules. Complete the row on your sequence sheet.
2. Using the corresponding mRNA codon sequence, determine what the anticodon would be on the tRNA carrying that amino acid to the ribosome. Complete the row on your sequence sheet.
3. Using the mRNA codon wheel provided by your teacher, determine the sequence of amino acids that each codon represents. Complete the row on your sequence sheet.
4. It is important to note that the process of transcription and translation will occur for each new generation in the dinosaur family!
5. Use the chart titled "Amino Acid Sequence for Traits" to determine the phenotypic characteristics encoded by each of the genes for your dinosaur.
6. Write the allele for each gene in the chromosome diagram starting at the top and working down. (See example below)
7. Using the alleles of each parent homologous chromosome, fill in the "Genotype and Phenotype of Parent" chart. Be sure you clearly illustrate homozygous or heterozygous genotypes in your table. Use *your* chromosomes and the table "How Genes Are Expressed" to determine the phenotype for traits that are expressed with complete or incomplete dominance.
8. Synthesize a detailed diagram of your mother or father dinosaur, labeling all 10 phenotypic characteristics. Label whether the traits of your dinosaur are dominant or recessive.



Grading Part 1: Synthesizing the Parents

Content	Criteria	Learning Expectation	Point Value	Points Earned
DNA, mRNA, tRNA amino acid sequence chart	Execution: Completes all important components of the task (The amino acid sequence sheet is complete and correct)	Problem-solves and reasons effectively	10	
Parent genotype & phenotype	Strategy: Utilizes the "Genetic Code Wheel" to go through the solution process that leads to the correct identification of the genotype and phenotype of the parent dinosaur.	Problem-solves and reasons effectively	5	
Diagram/ presentation of parent	Conclusion: communicates results effectively by including a diagram of the parent that is complete. Effectively utilizes relevant vocabulary to describe the central-dogma process leading to expressed traits.	Problem-solves and reasons effectively	10	
Writing prompts	Communication: Using supporting evidence from text and electronic resources the student will organize, analyze, and synthesize a response to the question. Word choice and syntax are accurate and appropriate. The student shows mastery in the conventions of Standard English in the written assignment.	Communicates data and reasoning effectively	15	
Point Total			**40**	

Your grade: ______________________

Part 2: Making a Baby: Summative Assessment

21st-Century Skills Demonstrated:

- Learning and Innovation Skills
  3. Critical thinking and problem solving
  4. Communication and collaboration

Objective

The purpose of part 2 is to use the gametes made in part 1 to combine the genetic information from different dinosaurs to create a baby dinosaur.

Procedure

1. Let's assume that over the last few weeks, some new dinosaurs have joined the herd, increasing the variety of gametes (egg and sperm) present in the population. In the front of the room, there are two beakers, one containing all of the mothers' eggs and the other containing all of the fathers' sperm from part 1. Select one gamete from each of the beakers. The sperm will fertilize the egg, creating the developing zygote.
2. Staple the gametes to your data page so that you are able to refer back to them for reference.

3. Use the genotypes encoded by the gametes to fill in the "Genotype and Phenotype of the Offspring" chart for the new baby dinosaur. Taking into consideration whether the genotypes are dominant or recessive, state the phenotypes.
4. You will prepare a detailed diagram depicting the phenotypic characteristics of the new baby dinosaur. For extra credit, you will have the option to create a three-dimensional model of your offspring dinosaur. Label whether the traits of your dinosaur are dominant or recessive. Make sure all of the traits are correctly represented.

Grading Part 2: Offspring Representation

Content	Criteria	Learning Expectation	Point Value	Points Earned
Offspring genotype & phenotype	Strategy: Utilizes the "How Genes are Expressed" table to go through the solution process that leads to the correct identification of the genotype and phenotype of the offspring. The sperm and egg are stapled to worksheet	Problem-solves and reasons effectively	5	
Diagram or model of offspring	A clearly depicted model or diagram is created illustrating the genotypes and phenotypes of the expressed traits from the combination of parent genes.	**MODEL**	15 **+5**	
Presentation of media	Strong awareness of audience in the design. Students can clearly explain the process demonstrated. All terms/processes included. Media format is neat, detailed, and organized.	Communicates data and reasoning effectively	15	
Extension project	Communication: Using supporting evidence from text and electronic resources the student will organize, analyze, and synthesize a media project to accurately depict the importance of the central dogma in a biological organism. The student shows mastery in the conventions of Standard English in the written assignment.	Communicates data and reasoning effectively	15	
Point Total			**50**	

Your grade: ______________________