How Can We Design Cattle to Better Meet Human Needs?

DEVELOPER: American Farm Bureau

GRADE: HS | **DATE OF REVIEW:** December 2021

How Can We Design Cattle to Better Meet Human Needs?

EQuIP RUBRIC FOR SCIENCE EVALUATION

OVERALL RATING: R

TOTAL SCORE: 5

CATEGORY I: NGSS 3D Design Score	CATEGORY II: NGSS Instructional Supports Score	CATEGORY III: Monitoring NGSS Student Progress Score
2	2	1

Click here to see the scoring guidelines.

This review was conducted by NextGenScience using the EQuIP Rubric for Science.

CATEGORY I CRITERIA RATINGS			CATEGORY II CRITERIA RATINGS			CATEGORY III CRITERIA RATINGS		
A.	Explaining Phenomena/ Designing Solutions	Extensive	**A.**	Relevance and Authenticity	Adequate	**A.**	Monitoring 3D Student Performances	Inadequate
B.	Three Dimensions	Adequate	**B.**	Student Ideas	Extensive	**B.**	Formative	Adequate
C.	Integrating the Three Dimensions	Extensive	**C.**	Building Progressions	Inadequate	**C.**	Scoring Guidance	Inadequate
D.	Unit Coherence	Inadequate	**D.**	Scientific Accuracy	Extensive	**D.**	Unbiased Tasks/Items	Extensive
E.	Multiple Science Domains	Adequate	**E.**	Differentiated Instruction	Adequate	**E.**	Coherence Assessment System	Adequate
F.	Math and ELA	Inadequate	**F.**	Teacher Support for Unit Coherence	Extensive	**F.**	Opportunity to Learn	Adequate
			G.	Scaffolded Differentiation Over Time	Adequate			

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Summary Comments

Thank you for your commitment to students and their science education. NextGenScience is glad to partner with you in this continuous improvement process. The unit is strong in many areas, including providing coherent and engaging three-dimensional learning opportunities for students. The anchor phenomenon drives instruction in most of the unit and student ideas are elicited, respected, and used to motivate student learning.

During revisions and/or use in the classroom, the reviewers recommend paying close attention to the following focus areas in order to strengthen materials:

- Development and use of high school-level Science and Engineering Practices (SEPs), and Crosscutting Concept (CCC) elements. Although students have many opportunities to use SEP and CCC elements in the materials, most of these opportunities use unclaimed elementary or middle school-level SEP and CCC elements. Students currently have little support to develop new understanding of these two dimensions.
- Assessment support for SEP and CCC elements. As with the learning opportunities, assessments currently focus primarily on supports related to Disciplinary Core Ideas (DCIs). Scoring guidance and formative assessment supports provide very few opportunities for teachers and students to monitor student performance in high school-level SEP and CCC elements.
- Connections to mathematics and literacy standards. Students have many opportunities to apply mathematics and literacy standards in their sense-making, but these opportunities are not explicitly labeled so the chance to make meaningful connection between disciplines might be missed.

Note that in the feedback below, black text is used for either neutral comments or evidence the criterion was met, and purple text is used as evidence that doesn't support a claim that the criterion was met. The purple text in these review reports is written directly related to criteria and is meant to point out details that could be possible areas where there is room for improvement. Not all purple text lowers a score; much of it is too minor to affect the score. For example, even criteria rated as Extensive could have purple text that is meant to be helpful for continuous improvement processes. In these cases, the criterion definitely WAS met; the purple text is simply not part of the argument for that Extensive rating.

Unless otherwise specified, page numbers in this report refer to the page numbers listed on the referenced document's PDFs. For example, the page number after a comment about Lesson 1 refers to the page in the Lesson 1 document.

CATEGORY I

NGSS 3D DESIGN

I.A. EXPLAINING PHENOMENA/DESIGNING SOLUTIONS

I.B. THREE DIMENSIONS

I.C. INTEGRATING THE THREE DIMENSIONS

I.D. UNIT COHERENCE

I.E. MULTIPLE SCIENCE DOMAINS

I.F. MATH AND ELA

I.A. EXPLAINING PHENOMENA/DESIGNING SOLUTIONS

Making sense of phenomena and/or designing solutions to a problem drive student learning.

i. Student questions and prior experiences related to the phenomenon or problem motivate sense-making and/or problem solving.

ii. The focus of the lesson is to support students in making sense of phenomena and/or designing solutions to problems.

iii. When engineering is a learning focus, it is integrated with developing disciplinary core ideas from physical, life, and/or earth and space sciences.

Rating for Criterion I.A. Explaining Phenomena/Designing Solutions	*Extensive* *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that learning is driven by students making sense of phenomena because learning is driven by students figuring out an anchor phenomenon, investigative phenomena, and completing a design challenge related to a problem to solve. Students return to the anchor phenomenon, super cattle, throughout the unit, adding new learning to their understanding of the role of inheritance, DNA, and proteins. In the first part of the unit students figure out how heritable traits are related to the structure and function of proteins. The second part of the unit engages students by exploring the role of the environment related to variation and expression of traits. A design challenge is used to apply learning at the end of the unit, although it is only tangentially connected to a real-world problem.

The focus of instruction for most of the unit is making sense of the phenomenon, super cattle. Students regularly (almost daily) return to the phenomena and problems to add layers of explanation or iterate on solutions based on learning. Related evidence includes:

- Lesson 1: Before students see the phenomenon, they are engaged in categorizing different types of cattle based on their characteristics. Then students are introduced to the anchor phenomenon, "super cattle" through slides (page 15). Students are asked to make observations of the super cattle and compare them to the regular cattle (pages 15–16), and then are asked to try to explain what makes the cattle different: "Develop an initial model to explain what you think makes 'super cattle' 'super' compared to normal cattle? Try to explain what happens ***inside*** the organism as well as ***outside*** the organism that causes variation in traits. Use pictures, symbols, and words in your model to help represent and explain what you think is happening" (Slide 38).
- Lesson 2: Students are introduced to a specific animal that represents super cattle, Blue. The lesson focuses on students determining what they already know and don't know about what might cause Blue's double muscles, including developing initial explanatory models.
- Throughout the unit, students update their model trackers to track progression on what they figure out that helps them explain the Blue super cattle phenomenon (e.g., Lesson 2, page 22).

- Lesson 3: Students are facilitated to come up with the investigative phenomena that Blue somehow got from one cell to many cells, and that Blue's first cell (fertilized egg) looks different from his muscle cell today (page 8). Learning in the lesson focuses on the first phenomenon and learning in Lesson 4 focuses on the second (that Blue went from one cell to many different kinds of cells).
- Lesson 4: In the beginning of the lesson, students are asked to write down their initial ideas and then draw initial models to explain how Blue went from one cell to many different kinds of cells (page 7). At the end of the lesson, the teacher is told, "Have students individually write down in their Model Trackers what they have figured out so far about how Blue got so many different types of cells" (page 16).
- Lesson 5: Learning in the lesson focuses on figuring out the investigative phenomenon that different genes are "on" (expressed) or "off" in different cells.
- Lesson 9: The lesson begins a new focus on solving a problem: global food insecurity. However, this problem isn't stated as such and isn't presented to students directly. Instead, the teacher is told to, "SAY: Is Blue's mutation a trait that is useful in some way to addressing global food insecurity?" (page 5). This sentence is the only introduction students have to this problem, and the problem is not made more concrete (e.g., showing data on food insecurity or showing stories of people who don't have enough food). In the lesson, student learning is related to solving this problem. Students revisit the anchor phenomenon as they begin to research genetic variety in cattle breeds and begin to develop an understanding of how this variety can be used to address global food insecurity.
- Lesson 10: Students are shown an investigative phenomenon of an illustration of chromosomes of parents and children that don't match exactly. Students are asked, "What are some of your ideas of the structures and scales we need to investigate to know what is going on here? Feel free to use the Model Component Cards to help you out" (page 5).
- Lesson 11: Students focus on the investigative phenomenon that Blue, and his family members have differently sized muscles. Student work to gather information to understand this phenomenon during the lesson. At the end of the lesson the teacher is told, "Work with students to take stock of what is known and what needs to be figured out since what we expected, based on classic genetics does not explain the actual genetic makeup of the siblings. Create an anchor chart for the big ideas" (page 23).
- Lesson 13: Students are introduced to the investigative phenomenon that clones don't always have the same traits as the original animal (slide 4).
- Lesson 14: The lesson closes with a question unrelated to a problem. It is stated as this design challenge, "We recall that the driving question for this unit is 'What does it take to make super cattle?' and we are wondering if we can design our own Super cattle" (page 9).
- Lesson 15: The teacher is told, "We are introduced to the complex problem of animal production and the goals for animal production to meet the demands of a growing human population" (page 1). However, "animal production" per se is not a problem.
- Lesson 15: The lesson begins with this prompt, "Let's revisit our cattle cards to remind ourselves of some of the other traits cattle have and how those traits help to meet human needs. Maybe this will help us think about potential mates for Blue" (page 6). The stated focus of the lesson is

therefore on a design task rather than solving a problem. This task is connected to meeting human needs, but not to a concrete problem. Later in the lesson, students are prompted, "Turn and talk with a partner and determine what problem is identified here and how it is related to our study of super cattle" (page 8). An expected student response is, "The problem is the growing population of people." At this point, this problem is not directly connected to the design challenge, which follows immediately after this problem is stated: "SAY, We have done a lot of investigating super cattle and their traits. This is the work that cattle geneticists do to improve cattle genetics. Your challenge is to design a super herd of cattle" (page 8). The very last task of the unit lays out the connection between the problem and the design of a cattle herd (Student Task Geneticist, page 2). Students identify the desired traits in a herd of super cattle, classify the desirable and undesirable traits in mates, environmental factors, and the genetic technologies needed to implement their plans (pages 8–9).

The phenomena used in the unit closely match the targeted scope of student learning in the science DCIs. Listed under Criterion I.B are the targeted DCI elements that are identified in the unit materials and that help students explain the unit phenomenon of Super Cattle along with the lessons in which these DCIs are addressed.

Student questions drive much of the learning in the unit. Materials provide structured support for teachers to draw out student questions in order to make connections to motivate student learning. Students have frequent opportunities to feel as if they are driving the learning sequence. Related evidence includes:

- Lesson 1: "Say, I know some of you are more familiar with cattle than others and it seemed like everyone has some questions about cattle that we could answer in a quick internet investigation. Take just a minute or two to jot down some of the things you are wondering about cattle" (page 11).
- Lesson 1: "Remind students to consider all the related phenomena we just listed, along with all the work we did on our initial models and with our observations and questions we recorded previously (be sure these are within view)… 'Let's take some time to record all of the questions we have about Super Cattle. Once you have recorded your questions, put a start by one or two that you think we should investigate first'… 'We have so many questions to explore! How could we start to find answers to some of these questions? Take a few minutes to write your thoughts about how we might be able to try to answer some of the questions you have. Direct students to turn and talk with a neighbor to share one or two of their ideas'… 'We have lots of really great questions and ideas to investigate together. It seems like there are a lot of questions focused on Blue and his 'super' appearance. It seems like maybe if we figure out what causes him to be super it might help us understand other super cattle too. What do you think, should we learn some more about him?' Listen for agreement" (page 19).
- Lesson 2: A teacher note talks about the negative effects of the mutation under study and says, "As students pose concern for the animals, it is important to remain curious about and use their concern as an opportunity to add that question to the DQB to investigate" (page 4).

- Lesson 2: After students develop initial models, the teacher is prompted to say, “So we know time matters in the making of Blue, but I noticed that many of you had ideas related to different structures as you talked about what you noticed and wondered from the video and from what you put in your timeline models of Blue” (page 9). This connects to the next discussion, therefore using student ideas to transition.
- Lesson 2: Differences between different student models are highlighted to point out the need to learn more in order to resolve the areas of disagreement (e.g., page 14).
- Lesson 2: The class builds a Driving Question Board (DQB). The teacher is told, “SAY, So we have been thinking about how we can explain super cattle and Blue at various scales. Let’s take some time to find all of the questions we have about super cattle, Blue and what it takes to make ‘super’ muscles and start building our Driving Question Board. Look back at the questions you had in your Learning Log from lesson 1 and lesson 2, and that you recorded during our modeling, and write them out for others to see” (page 18). The teacher is also told, “It will be important to work with students to write these questions as Investigative questions” (page 19).
- Lesson 2: The teacher is prompted to ask, “‘How could we start to find answers to some of these questions? Take a few minutes to write your thoughts about how we might be able to try to answer some of the questions we have on our DBQ.’ Direct students to turn and talk with a neighbor to share one or two of their ideas” (page 21). “‘If we want to understand how Blue grew to have such super muscles, where should we start to understand his story?’ Accept all student responses but call attention to those that include conception, fertilization, Blue as a calf—that allow for investigating mitosis. SAY, ‘You have so many good ideas to investigate. Does it make sense to look at how Blue’s muscles got so big? How did he grow these massive muscles?’” (page 23).
- Lesson 3: “SAY, Let’s take a minute to think about what scales and structures we need to investigate to understand how baby Blue became a one ton super bull with many more muscle cells than a regular bull and also where we should be investigating in Blue’s Timeline. Have students get together with their partners and get out their scale model component cards (or graphic organizers) and identify which components they need to investigate to figure this out. Students will also want to reference their Temporal Model from L1…Look and listen for groups with varying answers, including one who has identified the cell card, and ask them to share with the class why this is the scale to investigate. ‘Because Blue started as one cell’” (page 7).
- Lesson 3: “‘So let’s take what we know back to Blue. Now that we know how mitosis works, how does it help us explain Blue and other cattle? Take a moment to think about Blue’s massive muscles. What would make them more massive?’ Tell students you have some data from 2 different research studies that might help them determine if mitosis in Blue is the same or different from other cattle. In this task, you will work with a partner to analyze patterns in data to use as evidence to determine if mitosis in Blue is the same or different from other cattle” (page 16). This new activity is introduced without connecting explicitly to student questions.
- Lesson 4: At the beginning of the lesson, the teacher is told, “SAY, Remember last time we were wrestling with the fact that all of Blue’s cells have the same genes, even the myostatin mutation, are all of his cells really the same? So what questions does that leave us with? Reference the DQB for questions that we can answer in this lesson” (page 6).

- Lesson 4: After students express their initial ideas about explaining the investigative phenomenon, the teacher is told, "Lead the class in a discussion around the similarities and differences in their drawings. Use this conversation to identify what we agree on and where we need to investigate further by keeping a class record" (page 7).
- Lesson 4: "Pose the Question: 'What do you think is causing these cells to look different? Turn and talk.' Listen for answers that might be on the right track-genes. If brought up, use a line of questioning to get students to share what they think might be going on with genes. SAY: 'I am hearing some of you say we need to look at the genes of cells to explain why they are different. How about we look there?' If you don't hear students talking about genes you can use the following line of questioning to elicit that idea. 'Can we tell from this picture what is causing these cells to look different? Can we tell what is causing them to divide at different rates? Where do we need to look?'" (pages 9–10).
- Lesson 5: "Reference the DQB for questions that we can answer in this lesson.…Take out your model component cards and decide what structures and scales we need to investigate to see genes like myostatin turned on and off. Allow students a few minutes to talk through their ideas and then ask students to share their thinking. Accept all ideas so long as they are scales smaller than the cell. SAY, It seems like many of you agree that if we want to 'see' genes, we need to be looking at the chromosome" (page 6).
- Lesson 5: The lesson ends by having students think about what they need to figure out next. "Use talk moves to elicit ideas about gaps in our models, particularly that we don't know how proteins are actually made….SAY, I am hearing some of you say you think that we need to figure out how protein is made. That this will help us to understand Blue and how he is different from other cattle. Let's do that!" (page 16).
- Lesson 6: "Use talk moves to help students recognize this potential gap—that maybe we don't know what the 'code' is.…Say, I am hearing that we need to know more about the details of how protein is being made, like what cell components are needed and the functions of those cell parts. What are some of your ideas for how we can figure this out?" (page 7).
- Lesson 6: "It will be important in this discussion to help students recognize that we still can't explain how the DNA code is translated into amino acids. Problematize the idea that the DNA molecule is too large to get outside of the nuclear pore and the proteins are too large to move in and out. There must be something happening that we can't explain yet with the components we have. Say, I think I have some additional information that may help us out" (page 10).
- Lesson 7: "Say: 'Take a few minutes to Jot[sic] down questions you have about which part of our explanation for Blue we don't have answers for yet. Take out your Model Component Cards and find the components you think we need to investigate. Once you have done your own thinking and recorded it in your learning log, share with a partner'…. Reference the DQB for questions that we can answer in this lesson" (page 5).
- Lesson 8: At the end of the lesson, the teacher is prompted to say, "Work with students to take stock of what is known and what needs to be figured out next. ASK, What can we figure out by investigating scales larger than Blue? Listen for these ideas: We can figure out how he got the mutation in the first place. ASK, What questions might we be able to answer by zooming out? Revisit the DQB to identify remaining questions" (page 7).

- Lesson 9: "Use talk moves to elicit ideas about gaps in our models, particularly that we don't know how genetic traits are actually passed to offspring in organisms. Sample Responses: We don't know how genetic traits are passed from parent to offspring. We know his parents had extra muscles, but we don't know if they were super muscles like Blue. What traits do his parents actually have that they passed onto Blue? Sample responses: What do Blue's family members look like? Say, I am hearing some of you say you think we need to begin investigating things that are outside of Blue. Is that right? Pause for affirmation. Say, This makes me think we have got a good start zooming out on cattle breed usefulness and that we need to investigate how this variation came to be" (page 8).
- Lesson 10: The activity is teacher driven but it is connected to student questions. "Say, I think it is time that we gather some information about the process by which sperm and egg cells are made in the bodies of sexually reproducing organisms. Do you think that may help us answer our questions about the variation we saw in the chromosomes of Blue's family? Pause for agreement" (page 9).
- Lesson 11: "Tell students that the goal of this discussion is to figure out areas of agreement and disagreement in our initial models. Knowing where we agree and disagree will help us figure out how we might want to proceed in figuring out how the MSTN gene is inherited… Throughout the discussion, and again toward the end, remind students to record any questions they have right now in their science notebook so we do not lose those questions" (page 12).
- Lesson 11: "SAY, Now that you have figured out the pattern of inheritance explaining the genes that determine the three muscle tissues in Blue's family and gender, it is time to gather some additional information about inheritance of traits that will help us better explain Blue and his family. Select one article to read, Simple Inheritance in Beef Cattle, Inheritance of Traits by Offspring, and Genetic Dominance. Use the Close Read tips as you gather information about inheritance" (page 19). This activity is teacher driven but is connected to student questions.
- Lesson 13: "What stands out to you about [sic] last class? What are some questions we need to answer? Reference the DQB for questions that we can answer in this lesson" (page 5).

Students' prior experiences are elicited and used to support their learning in several parts of the unit. Related evidence includes:

- Lesson 1: The teacher is told to, "ASK: What do you know about other organisms and the relationship between their traits and purpose that might help us understand what makes Super Cattle 'super'? Take a moment and jot down your ideas and then we will make a class record of our related phenomena" (page 18).
- Lesson 2: "Ask for a show of hands from students who have seen a cow or bull like this before, or even another organism with big muscles. Have students share with their elbow partner about their experiences with 'double' muscled cattle or organisms. Listen for what they know about what causes these traits" (page 7).
- Lesson 12: Students are asked, "What do you know about mutations in general?" (slide 4). The teacher is told, "This is an opportunity to leverage what students have learned in middle school, in the unit, and what they bring from personal experience related to mutations. Allow student time to talk with an elbow partner then ask for volunteers to share out" (page 6).

- Lesson 12: "Suggested prompt: What do you know about other organisms with large muscles that might help us answer? Think about whether extra muscles are good or bad. Sample responses: Bodybuilders have large muscles and they seem to be fine. Having more muscles means more for humans to eat" (page 9).
- Lesson 14: Students are presented with a problem and then asked, "What techniques have you heard of that could solve this problem?" (Student Home Task, page 1).

Grade-appropriate science ideas are necessary for students to address the engineering design challenge in Lesson 15 of the unit. The last lesson of the unit is a design challenge, so engineering is used to apply the science learned in the unit. "SAY, We have done a lot of investigating super cattle and their traits. This is the work that cattle geneticists do to improve cattle genetics. Your challenge is to design a super herd of cattle" (page 8).

Suggestions for Improvement

Consider making the problem of food insecurity more concrete for students and more consistently used to drive learning and problem solving in the latter lessons of the unit.

I.B. THREE DIMENSIONS

Builds understanding of multiple grade-appropriate elements of the science and engineering practices (SEPs), disciplinary core ideas (DCIs), and crosscutting concepts (CCCs) that are deliberately selected to aid student sense-making of phenomena and/or designing of solutions.

i. Provides opportunities to *develop and use* specific elements of the SEP(s).

ii. Provides opportunities to *develop and use* specific elements of the DCI(s).

iii. Provides opportunities to *develop and use* specific elements of the CCC(s).

Rating for Criterion I.B. Three Dimensions	*Adequate* (*None, Inadequate, Adequate, Extensive*)

The reviewers found adequate evidence that the materials give students opportunities to build understanding of grade-appropriate elements of the three dimensions.

The targeted elements from each dimension are listed in the Storyline document along with some questions related to each element (e.g., page 8). A description is not given as to how the questions are to be used in the materials. In addition, the targeted elements listed in the Storyline do not match the targeted elements listed in the Lesson documents.

In the overview teacher materials, grade-appropriate elements of the three dimensions are not claimed as learning goals; only categories (e.g., “Patterns”) are claimed as learning targets. At the end of individual 5E sequences, though, element-level learning goals are claimed.

Science and Engineering Practices (SEPs) | **Rating: Adequate**

The reviewers found adequate evidence that students have the opportunity to use high school-level SEPs in this unit. Although students have many opportunities to use SEPs in general and students have opportunities to develop two of the **Obtaining, Evaluation, and Communicating Information** SEP elements, most of the SEP usage in the unit is at the middle school level or below, although it is claimed at the high school level. Students are not supported to develop or use the claimed high school elements in most cases.

In Lesson 13, a middle school-level SEP element is claimed but not designated as being middle school level.

Asking Questions and Defining Problems

- *Ask questions that arise from examining models or a theory to clarify relationships.*
    - Lesson 6: This element is claimed. Students examine models of how genes make proteins and then create questions about how DNA codes and the formation of the protein (Teacher Guide, pages 9–13).
    - Lesson 13: This element is claimed. “Throughout the discussion, and again toward the end, remind students to record any questions they have right now in their science notebook so we do not lose those questions. Say, Let’s take a few minutes to revisit our learning in Lesson 5 when we were investigating chromosome structure. Take a look at your learning logs, your chromosome models, and your trackers to see if there is anything there to help us out with our questions. What unanswered questions did we have?” (page 8).
- *Ask questions that arise from careful observation of phenomena to clarify and/or seek additional information.*
    - Lesson 1: This element is claimed. Students observe cattle and write down questions about what causes animals of the same species to not have so many different variations of traits (pages 8–9).
    - Lesson 2: This element is claimed. A few times in the lesson, student questions about the super cow phenomenon are elicited. For example: “Throughout the discussion, and again toward the end, remind students to record any questions they have right now in their science notebook so we do not lose those questions” (page 15), and “Let’s take some time to find all of the questions we have about super cattle, Blue and what it takes to make ‘super’ muscles and start building our Driving Question Board” (page 18).
    - Lesson 9: This element is claimed. The teacher is prompted, “Say, So we have been thinking about how we can explain super cattle and Blue at MACRO scales compared to other cattle breeds. Let’s take some time to capture the questions we have now about super cattle, Blue and the mutation to add to our Driving Question Board” (page 7).

- *Evaluate a question to determine if it is testable and relevant.*
  - Lesson 2: This element is claimed. As the class develops the DQB, the teacher is told, "If there are questions that don't fit within the proposed clusters of questions, engage students in a conversation about the relevance of the questions to the phenomenon under study. Ask students to clarify their reasoning to draw out the connections students are making with their questions" (page 19). The teacher also discusses testability. For example: "What is the difference between these two questions? [1] Do genes cause all of the super cattle traits? [2] How do genes cause super cattle traits? Listen for these ideas: The first one can be answered with yes or no. The second one requires that we investigate genes and traits. SAY, Let's take a good look at these questions and make sure they are written as investigative questions. An investigative question requires us to take action. What 'actions' would we take to investigate a question?" (pages 19–20). However, the two questions discussed here are both testable. This teacher prompt seems to indicate that yes/no questions are not testable and not questions that would "require us to gather information, obtain data, or conduct an investigation." See discussion of this issue under Criterion II.D.
- *Analyze complex real-world problems by specifying criteria and constraints for successful solutions.*
  - Lesson 15: This element is not claimed but is used when students are asked, "What are some criteria and constraints we should consider?" related to problems of human population and food insecurity (page 8). Students are also asked, "What are the cost, safety, and aesthetic constraints you need to consider for your super herd?" (Student Task, page 4).

Developing and Using Models

- *Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.*
  - Students model extensively throughout the unit. However, teacher answer keys for student models focus solely on the factual content of the models rather than on the features of high school-level modeling. Many times, students model their ideas (rather than evidence) and therefore use this middle school-level element rather than the claimed element: *Develop a model to describe unobservable mechanisms*.
  - Lesson 1: This element is claimed. Students are asked to make observations of the super cattle and compare them to the regular cattle (pages 15–16), and then are asked to try to explain what makes the cattle different. "Develop an initial model to explain what you think makes 'super cattle' 'super' compared to normal cattle? Try to explain what happens inside the organism as well as outside the organism that causes variation in traits. Use pictures, symbols, and words in your model to help represent and explain what you think is happening" (Slide 38). Although students implicitly model some relationships between systems, they show more evidence of using this middle school-level element: *Develop a model to describe unobservable mechanisms*.

- Lesson 2: This element is claimed. Students develop initial models to represent their thinking about the causes for the phenomenon at different scales (e.g., muscles, cells) (e.g., page 14). Students use this middle school-level element: *Develop a model to describe unobservable mechanisms*.
- Lesson 3: This element is claimed. Students develop models of Blue's first cell dividing. "Use the middle box to show what was happening with the cell while it was actively dividing-in between being one cell and two cells. The box on the left is for showing what the cell looked like, including its parts, before it divided. The box to the right is for showing what the cells looked like after division" (page 11). The teacher is also told, "Talking through components of the model provides scaffolding for students to begin to think about relationships between these components as they revise their initial models." Later in the lesson, students are asked to, "Look back at your initial model to explain what happens how Blue went from one cell to two cells. What can you add to or remove from your model based upon information you have gathered?" (slide 17).
- Lesson 4: This element is claimed. Students are prompted to, "Revisit your initial model to explain how Blue developed different cells from 2 cells in your Learning Log A. Use the space below to revise your model. Be sure to explain why a muscle cell, a fat cell, and a bone cell are different and to include the mutated gene" (Student Task, pages 10–11). Students also develop a model to explain cell differentiation and analyze data from microarray data so they can explain why the super cattle develop different types of cells (pages 6–14).
- Lesson 5: This element is claimed. Students build a physical model of a chromosome. "Using what you know about the size and chemical makeup of chromosomes, build a model of chromosome 2" (Student Task, page 1). After learning more information, students revise the model to include coding and non-coding regions of DNA and methyl groups (pages 8–15).
- Lesson 8: This element is claimed. In the review/assessment task, students are told, "Organisms which have double muscles have a mutation in their myostatin genes. Draw a model to show how a mutation in the DNA causes the muscles to be affected? Be sure to show what is happening to DNA and mRNA" (Student Task, page 2).
- Lesson 12: This element is claimed. Students are asked to gather and evaluate evidence and use the information to, "Develop a model that explains the effects of double muscles on the body component you investigated. Your model should include components from the cellular level to the organism level. Include labels for all components, describe the structure and function of the components, and identify and describe relationships between the components" (Student Task, page 1).
- Lesson 13: This element is claimed. "SAY, I want you to see if you can explain what causes a cow's phenotype to be different from its genotype. Use what you know about the relationships of these terms to explain differences. Use drawings and words to explain your thinking. Be sure to discuss what is happening outside and inside the cow….Give students 5-10 minutes to construct their models" (page 7).

- *Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena and move flexibly between model types based on merits and limitations.*
    - Lesson 6: This element is claimed. Students draw models and then develop models electronically with drag and drop components. "Have students model how they think proteins are made using the parts given. They can drag and drop, add parts, arrows or words. Students can draw, screenshot, or print their final products to add to learning logs. This could be done with physical cut outs to manipulate" (page 11). However, students use the model type they are told to use. They do not discuss the merits and limitations of different model types.
    - Lesson 11: This element is claimed. In the lesson students use physical models, drawn models, and Punnett squares as models. However, students use the model type they are told to use. They do not discuss the merits and limitations of different model types.

Analyzing and Interpreting Data

- *Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.*
    - This element is claimed in the introductory documents for the unit but not in any individual lesson.
    - Lesson 11: Students use the super cattle's family tree to trace the inheritance of the mutated DNA, create family Punnett squares and calculate genetic probabilities (Student Task Inheritance, pages 7–11). However, students only calculate ratios, so they instead use this Grade 6–8 element: *Apply concepts of statistics and probability (including mean, median, mode, and variability) to analyze and characterize data, using digital tools when feasible.*
- *Evaluate the impact of new data on a working explanation and/or model of a proposed process or system.*
    - Lesson 3: This element is claimed. In the lesson students are given data to analyze, using the data analysis to answer questions about the phenomenon (page 16). However, students do not discuss the fact that new data might have changed their explanations or models.

Constructing Explanations and Designing Solutions

- *Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.*
    - Lesson 3: This element is not claimed but students are asked to fill out a C-E-R scaffold page. The accompanying scoring rubric asks for evidence for the first part of this element.
    - Lesson 4: This element is claimed. Students are prompted to, "Explain what causes different cells to have different structures and different functions, even though they all

have the same genes" and then are asked to describe the relationship between components in their explanations (Student Task, page 9). For this same task, students are also told to, "Make sure you support your explanation with evidence from the analysis of the data" (page 13). However, the last part of the element is not evident in student explanations.

  - Lesson 8: This element is claimed. Students communicate scientific information during this review/assessment lesson, but they are not asked to construct explanations citing evidence and are not asked to recognize theories and laws continuing into the future.
  - Lesson 14: This element is claimed. Students are asked to communicate information they obtained from a variety of sources, but they are not asked to construct scientific information, and the scoring rubric only asks students to clearly communicate the information.
- *Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena.*
  - Lesson 7: This element is claimed. Students model phenomena and are asked to, "Use evidence from the diagram. Explain why the shape of myostatin is important to how it functions in muscle growth" (Student Task, page 2) but don't seem to be expected to construct a high school-level explanation. The Teacher Answer key for this prompt is "Myostatin must be properly shaped to fit the receptor and properly function," therefore, students aren't expected to connect evidence to reasoning in their explanations.
- *Apply scientific ideas to solve design problems, taking into account possible unanticipated effects.*
  - Lesson 15: This element is claimed. Students are introduced to the engineering design challenge, which focuses on the goals for animal production to meet the demands of a growing human population. Students identify the desired traits in a herd of super cattle, classify the desirable and undesirable traits in mates, environmental factors and the genetic technologies needed to implement their plans (pages 5–9). Students are also asked to, "Explain all the possible reasons why your calves might not display the traits (phenotype) you plan for them to have. (What are all the possible causes of variation of traits?)" (Student Task, page 6).
- *Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.*
  - Lesson 15: This element is claimed. Students are introduced to the engineering design challenge, which focuses on the goals for animal production to meet the demands of a growing human population. Students identify the desired traits in a herd of super cattle, classify the desirable and undesirable traits in mates, environmental factors, and the genetic technologies needed to implement their plans (pages 5–9). However, prioritized criteria and tradeoff considerations are not discussed.

Engaging in Argument from Evidence

- *Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence.*
    - This element is claimed in the introductory documents for the unit but not in any individual lesson. There is no evidence that students develop or use the element in the unit.

Obtaining, Evaluating, and Communicating Information

- *Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.*
    - Lesson 6: This element is claimed. Students are directed to find information about either DNA or proteins from a video or Internet research. Students are not directed to evaluate sources of information.
    - Lesson 7: This element is claimed. Students obtain and integrate information from various formats (e.g., Student Task, page 5), but are not directed to evaluate the sources.
    - Lesson 8: This element is claimed. The lesson reviews/assesses learning from the prior lessons in the unit, and students may be (depending on teacher choice) allowed to look back at their prior models, but the lesson itself does not require students to compare, integrate, or evaluate sources of information.
    - Lesson 10: This element is claimed. Students integrate information from three articles (Student Task, page 1) but do not need to compare or evaluate the sources of information.
    - Lesson 14: This element is claimed. Students are asked to find information and evaluate it with given criteria, such as "The ideas are presented without bias" (Student Task, page 2).
- *Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.*
    - Lesson 12: This element is claimed. In the "Mutations" task, students are supported to gather information from four readings and compare the ideas in the different articles (Student Task, page 2). Later during other readings, the teacher is prompted, "What are some things you will be looking for to know if the information is valid and reliable? Sample response: We will look to see if the website has current information, who is responsible for the information and whether the information is unbiased. A checklist is included in the research task to use as a guide. It is important to work with students to generate criteria to talk through the importance of valid and reliable evidence and information. As students generate a list or criteria, record them on the board. Include any new suggestions for criteria they want added" (page 11). The teacher is also told, "The articles have been specifically chosen to raise questions related to sufficiency of the evidence" (page 13).

    - Lesson 14: This element is not claimed, but students are asked to find information and evaluate it with given criteria, such as "The ideas are presented without bias" (Student Task, page 2).
- *Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts.*
    - Lesson 12: This partial element is claimed. As students prepare to read scientific texts, the teacher is prompted, "Suggested prompt: What are some things you will be looking for to know if the information is valid and reliable? Sample response: We will look to see if the website has current information, who is responsible for the information and whether the information is unbiased. A checklist is included in the research task to use as a guide. It is important to work with students to generate criteria to talk through the importance of valid and reliable evidence and information. As students generate a list or criteria, record them on the board. Include any new suggestions for criteria they want added. Say, Those ideas sound great. While you read, markup the text to track your thinking and as you find information" (page 11). The teacher is also told, "The articles have been specifically chosen to raise questions related to sufficiency of the evidence" (page 13).
- *Communicate scientific and/or technical information (e.g., about a proposed object, tool, process, system) in writing.*
    - Lesson 15: This element is claimed. In the student tasks, they are asked to provide scientific and technical information in writing. For example, student prompts include: "Why are EPDs a useful tool for selecting animals for a breeding program?" (Student Task EPDs #1) and "Explain how your design will meet the goals(s)" (Student Task Geneticist #5).

Disciplinary Core Ideas (DCIs) | **Rating: Adequate**

The reviewers found adequate evidence that students have the opportunity to use or develop the DCIs in this unit. Some of the targeted DCIs are thoroughly developed, but others (especially the ETS DCIs) are not used or developed in the unit.

The Storyline document includes a "DCIs Unpacked" section, but no description is given about how the teacher should use this information.

In Lesson 15, a middle school-level DCI element is claimed without noting that it is from middle school. Another sentence is included in the DCI claims list that is a Framework endpoint but is not in the NGSS: "The information passed from parents to offspring is coded in the DNA molecules that form the chromosomes."

LS1.A: Structure and Function

- *Systems of specialized cells within organisms help them perform the essential functions of life.*
    - Lesson 4: This element is claimed. Students build toward this understanding by comparing the different structures of muscle vs. bone vs. fat cells.

- Lesson 5: This element is claimed. However, the lesson focuses on chromosomes and DNA structure so does not directly develop this understanding.
- Lesson 8: This element is claimed. The lesson reviews/assesses what has been discussed previously in the unit, which focuses on muscle function (not a broadly applicable understanding of this element in general).

- *All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells.*
  - Lesson 6: This element is claimed. In the lesson, students explore the mechanisms of DNA transcription and translation into proteins.
- *Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level.*
  - Lesson 2: This element is claimed. Students discuss that cells and muscles are studied at different scales and that one makes up the other (e.g., page 11). Students therefore begin to develop this idea.
- *Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system.*
  - Lesson 7: This element is claimed. In the student task, students are asked to respond to the prompt: “Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system. Is the process of myogenesis when myostatin is mutated a positive or negative feedback mechanism? Explain your reasoning. (Feel free to use the internet to learn more about positive and negative feedback loops.)” (Student Task, page 7).

LS1.B: Growth and Development of Organisms

- *In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism.*
  - Lesson 3: This element is not claimed but students begin to develop it when they watch videos of mitosis (e.g., page 10).
  - Lesson 4: The last sentence of this element is claimed. Students examine microarray data and learn most of this claimed part of the element. However, although the teacher notes say (page 16) that students learn about the use of cell division for maintenance of an organism, this isn’t discussed in the lesson. The last part of the sentence also isn’t discussed.
  - Lesson 5: The last sentence of this element is claimed. The lesson focuses on how genes are turned on or off to continue explaining cellular differentiation. The last part of the sentence isn’t discussed.

- Lesson 8: The last sentence of this element is claimed. The ideas discussed so far in the unit are reviewed/assessed, therefore the last part of the sentence is not used.

LS3.A: Inheritance of Traits

- *Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function.*
  - Lesson 3: This element is claimed. Students discuss mitosis and the fact that DNA is contained in chromosomes. They therefore begin to build toward this element.
  - Lesson 5: This element is not claimed, but students begin to develop an understanding that DNA is a very long molecule relative to the size of a chromosome (e.g., page 10). They also read an article to learn information about non-coding regions of DNA (e.g., page 13).
  - Lesson 13: The third sentence of this element is claimed. Students learn about epigenetics and differential gene expression, therefore developing this claimed part of the element.
  - Lesson 14: The second sentence of this element is claimed. Students conduct research on various breeds of cattle and use this DCI information to understand their research results.

LS3.B: Variation of Traits

- *In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited.*
  - Lesson 10: The first sentence of this element is claimed. Students learn about meiosis in the lesson through videos and readings.
  - Lesson 12: The second sentence of this element is claimed. Students create a Mutations Mind Map, read about mutations, and compare models. Based on these activities, they summarize what they have learned about mutations (pages 7–9).
  - The last sentence of the element is not claimed and is not explicitly discussed in the unit.
- *Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus, the variation and distribution of traits observed depends on both genetic and environmental factors.*
  - Lesson 13: This element is claimed. Students learn about differential gene expression between twins and clones and therefore build toward this element.

- Lesson 15: This element is claimed. Students are told to, "Explain all the possible reasons why your calves might not display the traits (phenotype) you plan for them to have. (What are all the possible causes of variation of traits?)" (Student Task, page 6).

ETS1.A: Defining and Delimiting Engineering Problems

- *Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.*
  - Lesson 15: This element is claimed. Students are asked, "What are some criteria and constraints we should consider?" (page 8) but do not need to use this high school-level DCI understanding (including considerations of quantification) to complete the task.
- *Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.*
  - Lesson 15: This element is claimed. Students read about some major global challenges facing humanity (e.g., slide 8), and therefore begin building toward this element.

ETS1.B: Developing Possible Solutions

- *When evaluating solutions, it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts.*
  - Lesson 14: This element is not claimed, but the student home learning task presents students with a problem and then prompts them, "What other considerations should be made when solving this problem? Are there other perspectives to consider?" (Home Learning Task, page 1). Students therefore are prompted to begin considering the ideas behind this DCI element.
  - Lesson 15: This element is claimed. In the last student task, students are asked, "What are the cost, safety, and aesthetic constraints you need to consider for your super herd? Think about costs involved in genetic technologies, selective breeding, etc. What safety issues for humans or for the animals do you need to identify? To what extent is the organism's appearance important (e.g. horns, color, humps, etc.)?" They are also asked, "What are the cultural, social, and environmental impacts you should consider related to your super herd?" (Student Task, page 4). Students therefore begin to develop this understanding but are not expected to use it independently (e.g., to show understanding that it is important to take these issues into account). In this case, students simply follow directions, so it is unclear whether they would know to ask about cost, safety, aesthetics, or cultural, social, or environmental impacts on their own or in other contexts.

ETS1.C: Optimizing the Design Solution

- *Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.*
  - Lesson 15: This element is claimed. However, the ideas in this element are not discussed or used in the lesson.

Crosscutting Concepts (CCCs) | **Rating: Adequate**

The reviewers found adequate evidence that students have the opportunity to use or develop the CCCs in this unit. Several high school elements are implicitly used in student tasks. However, there is a significant mismatch between claimed elements and student performances in the unit. In addition, students do not have opportunities to explicitly develop an understanding of these high school-level elements.

A middle school-level **Structure and Function** CCC element is claimed in Lessons 3, 4, 5, and 8 without noting it as a middle school element.

Patterns

- *Empirical evidence is needed to identify patterns.*
  - Lesson 3: This element is claimed. Students are given data to analyze and asked to record patterns they noticed (Student Task, page 5), but there is no discussion of empirical evidence.
- *Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus, requiring improved investigations and experiments.*
  - Lesson 10: This element is claimed. Students are told to, "Draw an initial model to explain the chromosomes in Blue's family. Add MACRO scale components to explain what structures are involved and details at the micro scales that explain the patterns of genes on the chromosomes we observed" (page 6). Students therefore discuss different scales, but the ideas in this CCC element are not discussed.
  - Lesson 13: This element is claimed. The ideas in this CCC element are not discussed in the lesson.

Cause and Effect

- *Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.*
  - This element is claimed in the introductory documents for the unit but not in any individual lesson. The closest possible match for use in the unit is in Lesson 13, in which, after analyzing clone chromosome structure, students investigate the cause-and-effect relationships between organisms' phenotypes and genotypes (Teacher Guide, pages 5–9). However, there is no evidence that students use an understanding of this element.
- *Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.*

- Lesson 1: This element is claimed. In the beginning of the lesson, the teacher is told, “As you walk the room and monitor how the groups are sorting out their cards, feel free to push their thinking of how they are sorting their groups. Physical traits are going to be the main ways that they will sort out their groups, but if we can help them work through what is beyond what we can see to microscopic levels (e.g., chromosomes) the discussion will be much more enriching in the next step” (pages 9–10).
- Lesson 2: This element is claimed. Students collect information from a video and discuss initial ideas about DNA mutations being the cause of the macroscopic super cattle phenomenon (e.g., page 11).
- Lesson 4: This element is claimed. As students start to examine the investigative phenomenon, the teacher is prompted, “SAY, Let’s start with the idea that we need to know when Blue’s cells started changing. Where could we look? Which scales might have the answers we are looking for? (refer students to the Model Component cards to help them come up with answers)” (page 8). In the student task students are asked to respond to the prompts, “Where do we need to zoom in to see what causes cells to have different traits? To see Blue’s mutation? What are the structures we would be observing?” and “At this scale (where we can see the mutation), what similarities and differences would be observable in these structures?” (Student Task, page 4).
- Lesson 6: This element is claimed. Students focus on figuring out how DNA mutations can cause the super cattle phenomenon by learning about DNA transcription and translation into proteins. The lesson ends with a class discussion meant to “move the class towards this question: ‘How does the change in the protein cause more muscle cells?’” (page 15).
- Lesson 7: This element is claimed. Students focus on how the microscopic shape of proteins affects the macroscopic phenomenon of super cattle.
- Lesson 8: This element is claimed. Students respond to the prompt, “Organisms which have double muscles have a mutation in their myostatin genes. Draw a model to show how a mutation in the DNA causes the muscles to be affected? Be sure to show what is happening to DNA and mRNA” (Student Task, page 2). Students also respond to this prompt, “Mutations affect DNA at microscopic scales. Why is it important to look at macroscopic scales to understand the effects of mutations on an organism?” but the answer key exemplar response does not require understanding of this CCC element: “As these mutations are passed along from one generation to the next, you are able to see exactly how the mutation is expressed in those organisms. This can lead to a better understanding of what positive/negative impact it has on the species’ survival” (Teacher Key, page 3).
- Lesson 9: This element is claimed. In the lesson students discuss ways that cattle traits might contribute to alleviating global food insecurity, but do not talk about the different scales involved, other than the teacher saying that the class is “zooming out.” This element is not used explicitly.
- Lesson 12: This element is claimed. Students model the effects of genetic mutations on muscles and the full organism. The teacher is also prompted, “Ask, What scales did we

see the MSTN mutation in this lesson? Feel free to use your model component cards. Listen for these ideas: We saw the MSTN gene in many other organisms so that takes us to populations and communities. Ask, What can we add to our timeline to explain Blue and his mutation? Listen for these ideas: We know Blue's mutation has harmful effects on his body" (page 16).

  - Lesson 13: This element is claimed. Students learn about epigenetic mechanisms that affect organism traits.
  - Lesson 14: This element is claimed. Students conduct research on various breeds of cattle and need this CCC to understand their research results.
- *Systems can be designed to cause a desired effect.*
  - Lesson 15: This element is claimed. In the lesson students design cattle breeding schemes to produce desired results, such as higher milk production.

Scale, Proportion, and Quantity

- *The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.*
  - Lesson 12: This element is claimed. Students model the effects of genetic mutations on muscles and the full organism. The teacher is also prompted, "Ask, What scales did we see the MSTN mutation in this lesson? Feel free to use your model component cards. Listen for these ideas: We saw the MSTN gene in many other organisms so that takes us to populations and communities. Ask, What can we add to our timeline to explain Blue and his mutation? Listen for these ideas: We know Blue's mutation has harmful effects on his body" (page 16). The idea from this CCC element is implicit but not explicit in the lesson.
- *Some systems can only be studied indirectly as they are too small to observe directly.*
  - Lesson 2: This element is claimed. Students begin to build toward this idea through class discussion about spatial scales. "Think about the size of those structures—at what scales are they visible? Can we see them with the naked eye, or do we need microscopes and other tools to observe them?" (page 9). However, the class does not discuss the need to study these small scales indirectly. Students may think microscopes would be sufficient.
  - Lesson 6: This element is not claimed, but is partially used, especially the part of the element not claimed in the unit (e.g., "*too fast, or too slow to observe directly*"): "Why do you think this is a video animation—drawings that have been made into a video—and not an actual video of this process? Listen for these ideas: The process may be too fast or too slow to see. The process happens at a tiny scale that can't be seen" (page 12).
- *Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).*
  - This element is claimed in the introductory documents for the unit but not in any individual lesson. It is also not used in the unit.

Systems and System Models

- *Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions — including energy, matter, and information flows — within and between systems at different scales.*
    - Lesson 2: This element is not claimed but students start to build toward it as they develop models. The teacher is told, "SAY, I want you to see if you can explain what is going on with Blue at the different scales we have been talking about. Use what you know about how complex organisms like Blue are organized to help you think about the different scales and structures INSIDE Blue that cause or are related to his double muscle trait. Add arrows and words to show connections between the different scales and structures to help explain what is going on with Blue" (page 11).
    - Lesson 6: This element is claimed. In the lesson students use a computer model to simulate DNA transcription and translation.
    - Lesson 11: This element is claimed. In the lesson students use various models, including a physical model to show DNA movement between parent and child and how the information flows between systems at different scales (pages 8–10).
    - Lesson 13: This element is claimed. "SAY, I want you to see if you can explain what causes a cow's phenotype to be different from its genotype. Use what you know about the relationships of these terms to explain differences. Use drawings and words to explain your thinking. Be sure to discuss what is happening outside and inside the cow" (page 7).
- *When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.*
    - Lesson 7: This element is claimed. Students are asked to define boundaries, but it is not clear that they understand that the boundaries need to be defined. "Define the boundaries of the system needed to model how myostatin affects muscle growth. Think about the scale needed to see all of the model components. Feel free to draw and use words to describe the boundaries" (Student Task, page 7).
    - Lesson 15: This element is claimed. In the Mate Selection Task, students are asked, "What are all of the inputs and outputs of a breeding system that includes Blue?" "What are the boundaries of a breeding system that includes Blue? Explain why you identified those boundaries. Think about the largest scale that helps explain all of the factors that need to be considered when thinking about breeding programs" (Student Task, page 3) However, the Teacher Answer Key only says, "Due to Blue's myostatin mutation, it is important to strongly consider complementary breeds in developing a system including him" (Teacher Key, page 4), so students are not expected to show an understanding of the element.

Structure and Function

- *Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.*
  - Lesson 4: This element is not claimed but it is partially used when students are asked to respond to the prompt "Where do we need to zoom in to see what causes cells to have different traits? To see Blue's mutation? What are the structures we would be observing?" (Student Task, page 4).
  - Lesson 6: This element is claimed. In the lesson students examine the structure of DNA and the proteins that result from DNA mutations. They therefore build toward this element.

Suggestions for Improvement

General

- Consider listing all targeted elements in the Storyline document so educators have a single reference for all the learning students are expected to do in the unit.
- Consider providing students more opportunities to develop high school-level SEP and CCC elements.
- Where students are not intended to develop or use full elements, consider clarifying the learning targets through strikeout text, bolding, or explanatory language.

Science and Engineering Practices

- Consider identifying one or more select SEP elements for students to develop during each bend as key targets and providing supports for students to increase their learning in those prioritized elements.
- Lesson 12: Consider prompting the teacher to collect evidence of students' prior knowledge of the Grade 6–8 element: *Gather, read, synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used*. The class discussion of evaluating evidence could then build on this prior knowledge to ensure that students don't feel it is repetitive.

Disciplinary Core Ideas

Consider either including more opportunities for students to develop the ETS DCIs or removing them from the learning goal lists.

Crosscutting Concepts

- The targeted CCCs are identified in both the Storyline, front matter of the lessons, and Assessment Overview document. However, the use and development of the claimed CCC elements by students is not always clear in the body of the lessons. Consider opportunities to make CCC element use and development more explicit during lessons. Consider explicitly calling out where students can develop understanding of the CCC elements over time.

- Consider providing support for teachers to help students think explicitly about the CCC elements and how they are helpful in figuring out the phenomena.

I.C. INTEGRATING THE THREE DIMENSIONS

Student sense-making of phenomena and/or designing of solutions requires student performances that integrate elements of the SEPs, CCCs, and DCIs.

Rating for Criterion I.C. Integrating the Three Dimensions	Extensive *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that student performances integrate elements of the three dimensions in service of figuring out phenomena and designing solutions to problems. Students learn three-dimensionally much of the time in the unit, although the SEPs and CCCs used are below the high school-grade level in most activities. For example, in Lesson 5, no high school CCC element is claimed or used. Most of the student learning applies middle school-level SEPs and CCCs. However, there are numerous examples of three-dimensional learning where all three dimensions are grade appropriate and necessary for sense-making.

Related evidence includes:

- Three-dimensional Lesson-level Performance Expectations (LPEs) are listed for each lesson, although students are often not required to perform at the high school level during the lessons. See Criterion I.B for evidence related to individual elements of each dimension.
- Some high school-level three-dimensional performances are listed below (see evidence for student use under Criterion I.B):
  - Lesson 6: “Students develop and use multiple types of models to provide a mechanistic account to simulate information flows from DNA to protein formation” (pages 6–7).
    - SEP: **Developing and Using Models**: *Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, ~~and move flexibly between model types based on merits and limitations~~.*
    - CCC: **Systems and System Models**: *Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions— including energy, matter, and information flows—within and between systems at different scales.*
    - DCI: **LS1.A: Structure and Function**: *All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells.*

- Lesson 11: Students use various models, including a physical model to show DNA movement between parent and child.
  - SEP: **Developing and Using Models**: *Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, ~~and move flexibly between model types based on merits and limitations~~.*
  - CCC: **Systems and System Models**: *Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions — including energy, matter, and information flows — within and between systems at different scales.*
  - DCI: **LS1.B: Growth and Development of Organisms**: *The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells.*
- Lesson 12: Students model the effects of genetic mutations on muscles and the full organism. The teacher is also prompted, "Ask, What scales did we see the MSTN mutation in this lesson? Feel free to use your model component cards. Listen for these ideas: We saw the MSTN gene in many other organisms so that takes us to populations and communities. Ask, What can we add to our timeline to explain Blue and his mutation? Listen for these ideas: We know Blue's mutation has harmful effects on his body" (page 16).
  - SEP: **Developing and Using Models**: *Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.*
  - CCC: **Cause and Effect:** *Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.*
  - DCI: **LS3.B: Variation of Traits***: In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited.*
- Lesson 14: "Students integrate and evaluate information about how different processes in living systems cause normal cattle and super cattle to be the same and different" (Teacher Guide, page 5).
  - SEP: **Obtaining, Evaluating, and Communicating Information**: *Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.*

- CCC: **Cause and Effect**: *Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.*
- DCI: **LS1.A Structure and Function**: *All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells.*

Suggestions for Improvement

Providing opportunities for students to engage in grade-appropriate SEPs and CCCs in all activities throughout the unit would increase opportunities for students to perform three-dimensionally at the high school level. See suggestions under Criterion I.B.

I.D. UNIT COHERENCE

Lessons fit together to target a set of performance expectations.

i. Each lesson builds on prior lessons by addressing questions raised in those lessons, cultivating new questions that build on what students figured out, or cultivating new questions from related phenomena, problems, and prior student experiences.
ii. The lessons help students develop toward proficiency in a targeted set of performance expectations.

Rating for Criterion I.D. Unit Coherence	*Inadequate (None, Inadequate, Adequate, Extensive)*

The reviewers found inadequate evidence that lessons fit together coherently to target a set of performance expectations (PEs). The storyline and learning is coherent for students throughout the unit; lessons build directly on prior lessons and materials make the links between lessons clear to the students, and students have regular opportunities to engage in asking questions based on what they have learned so far in the unit and revisit their questions in subsequent lessons. However, the lessons do not work together to give students opportunities to build proficiency in all of the claimed PEs. Very few of the requisite SEP and CCC learning goals are fully developed during the unit.

Learning is sequenced logically from the students' perspective and links are made between lessons. Related evidence includes:

- Lesson 1: To navigate to the next lesson, the teacher is told to say, "We have lots of really great questions and ideas to investigate together. It seems like there are a lot of questions focused on

Blue and his 'super' appearance. It seems like maybe if we figure out what causes him to be super it might help us understand other super cattle too. What do you think, should we learn some more about him? Listen for agreement" (page 19). Students are then reminded of this decision in the beginning of Lesson 2 (page 6).

- Each lesson begins with questions on a slide: "What stands out to you about last class? What were we wondering at the end? What are some questions we need to answer now?" (e.g., Lesson 2, slide 2).
- Lesson 2: Students do the same card sorting activity twice in this lesson, on pages 10 and 13. This is therefore repetitive rather than coherently developing understanding over time.
- Lesson 2: Toward the end of the lesson, students are asked to compare their work from the current lesson to that of the previous lesson to determine which focus is more helpful in explaining the phenomenon (page 17).
- Lesson 3: The lesson picks up right where the last one left off. "SAY, We also decided it makes sense to try to figure out how Blue grew such large muscles. Where in Blue's timeline does it make sense to look if we want to figure out how Blue and his muscles got so massive, where would we start?" (page 7).
- Lesson 3: Toward the end of the lesson, the teacher is told, "Refer back to the DQB for questions that have been answered" (page 16). At the very end, the teacher is told, "Pose the two questions ['What do we still need to figure out about Blue? What questions do we still have?'] to help us think about next steps. Use talk moves to elicit ideas about gaps in our models, particularly about the gap between Blue's first cell and Blue as we know him today. We only know how his muscle cells developed, what about all of his other types of cells? Where did they come from?" (page 18).
- Lesson 4: At the beginning of the lesson, the teacher is told, "SAY, Remember last time we were wrestling with the fact that all of Blue's cells have the same genes, even the myostatin mutation, are all of his cells really the same? So what questions does that leave us with? Reference the DQB for questions that we can answer in this lesson" (page 6).
- Lesson 4: At the end of the lesson, students are asked two questions, "What do we still need to figure out about Blue?", and "What questions do we still have?" (slide 22).
- Lesson 5: The lesson ends with a class discussion, and the teacher is told, "SAY, I am hearing some of you say you think that we need to figure out how protein is made. That this will help us to understand Blue and how he is different from other cattle. Let's do that!" (page 16). However, this discussion is ignored in the beginning of Lesson 6. Students are facilitated to ask new questions and then decide that they "need to know more about the relationship between genes and proteins. Let's start there" (page 6). This may seem repetitive to students.
- The class frequently returns to the DQB to see what has been answered. For example, at the end of Lesson 7: "Who can summarize some of your key findings? What questions can we answer on our DQB?" (page 10).
- Lesson 8: At the end of the lesson the teacher is told to, "Work with students to take stock of what is known and what needs to be figured out next. ASK, What can we figure out by investigating scales larger than Blue? Listen for these ideas: We can figure out how he got the

mutation in the first place. ASK, What questions might we be able to answer by zooming out? Revisit the DQB to identify remaining questions" (page 7).

- Lesson 9: At the end of the lesson the teacher is prompted to, "Use talk moves to elicit ideas about gaps in our models, particularly that we don't know how genetic traits are actually passed to offspring in organisms. Sample Responses: We don't know how genetic traits are passed from parent to offspring. We know his parents had extra muscles, but we don't know if they were super muscles like Blue. What traits do his parents actually have that they passed onto Blue? Sample responses: What do Blue's family members look like? Say, I am hearing some of you say you think we need to begin investigating things that are outside of Blue. Is that right? Pause for affirmation. Say, This makes me think we have got a good start zooming out on cattle breed usefulness and that we need to investigate how this variation came to be" (page 8). However, Lesson 10 begins with the following discussion: "Suggested Prompt: What stands out to you about last class? Sample Response: We don't know how the patterns of genes on the chromosomes get passed to offspring and get swapped. Suggested Prompt: What are some questions we need to answer? Sample Response: How do chromosomes swap DNA and how do sperm and egg cells have only 30 chromosomes?" (page 5). This expected response and lesson direction does not flow directly from the prior lesson (where students are asked "what do Blue's family members look like?").
- Lesson 13: The lesson begins with "Suggested navigation: What stands out to you about last class? Sample Response: We know there are lots of traits to consider in selecting a mate. What were we wondering at the end? Sample Response: What other factors affect trait expression? Reference the DQB for questions that we can answer in this lesson" (page 5).

The following PEs are claimed as the "NGSS Performance Expectations Bundle" for the unit and stated as targeted NGSS PEs (Front Matter, page 2). However, students have few opportunities to develop full proficiency in the related SEPs and CCCs of the science PEs and have very little exposure to any of the three dimensions for the ETS PEs. The ETS PEs are separated by a line, but the meaning of this separation is not mentioned. See related evidence under Criterion I.B:

- **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.*
- **HS-LS1-2**: *Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.*
- **HS-LS1-4:** *Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.*
- **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.*
- **HS-LS3-2:** *Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.*
- **HS-LS3-3:** *Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.*

- **HS-ETS1-1:** *Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.*
- **HS-ETS1-2:** *Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.*
- **HS-ETS1-3:** *Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.*

Suggestions for Improvement

Providing students with opportunities to build full proficiency in all of the claimed SEPs and CCCs in the target PEs could strengthen the evidence for this criterion. Alternately, consider modifying the PE claims to clarify that students are only intended to build partial proficiency during the unit.

I.E. MULTIPLE SCIENCE DOMAINS

When appropriate, links are made across the science domains of life science, physical science and Earth and space science.

i. Disciplinary core ideas from different disciplines are used together to explain phenomena.

ii. The usefulness of crosscutting concepts to make sense of phenomena or design solutions to problems across science domains is highlighted.

Rating for Criterion I.E. Multiple Science Domains	*Adequate* *(None, Inadequate, Adequate, Extensive)*

The reviewers found adequate evidence that links are made across the science domains when appropriate. The phenomena of super cattle can be fully explained using content with the life science domain. However, CCC use across science domains is not pointed out to students.

- Throughout the unit, students use the life science concept of genetics and heredity to explain how heritable traits are related to the structure and function of proteins, involving the claimed elements of **LS1.A, LS1.B,** and **LS3.A**. Students use the life science concept of epigenetics to explain the role of the environment in the variation and expression of traits, involving the claimed elements of **LS3.B**.
- Lesson 5: When students talk about methyl groups — atoms of carbon and hydrogen — they apply existing physical science understanding. However, an explicit link is not made for students such that they would necessarily realize they are applying physical science in a life science lesson.

- Students use CCC elements within the life sciences domains. However, links are not made to prior student use or possible future use of related CCC elements in other science domains.

Suggestions for Improvement

Consider supporting students to explicitly see how the CCC elements they use in life science can also be useful (or have been useful in the past) for them in other science domains.

I.F. MATH AND ELA

Provides grade-appropriate connection(s) to the Common Core State Standards in Mathematics and/or English Language Arts & Literacy in History/Social Studies, Science and Technical Subjects.

Rating for Criterion I.F. Math and ELA	Inadequate *(None, Inadequate, Adequate, Extensive)*

The reviewers found inadequate evidence that the materials provide grade-appropriate connections to the Common Core State Standards (CCSS) in mathematics and English language arts (ELA). CCSS connections in mathematics and ELA/Literacy are not listed in the Unit Front Matter or in the individual lessons. These connections are not called out during the lesson activities and there are no mentions of mathematics or ELA/Literacy connections despite obvious places to make connections.

Although explicit connections to ELA/Literacy or mathematics standards are not made, students have opportunities to use literacy and mathematics skills in the unit. For example:

- Lesson 5: Students read an article from the National Library of Medicine (page 12), showing varied reading material.
- Lesson 11: “Monitor students as they work. Students may need support to calculate probabilities using both Punnett squares. It may help to have them draw all the possibilities and then determine how a mathematical model can represent their drawings” (page 18).
- Lesson 11: ”SAY, Now that you have figured out the pattern of inheritance explaining the genes that determine the three muscle tissues in Blue’s family and gender, it is time to gather some additional information about inheritance of traits that will help us better explain Blue and his family. Select one article to read, Simple Inheritance in Beef Cattle, Inheritance of Traits by Offspring, and Genetic Dominance. Use the Close Read tips as you gather information about inheritance” (page 19).
- Lesson 11: “Read the information about other traits on Chromosome 2 to find out what we will add to our model” (page 20).
- Lesson 12: “Suggested prompt: Someone remind us, what types of information are we hoping to find in these articles? Sample response: We need to know if there is anything bad that happens to organisms when they have double muscles. Suggested prompt: Okay, so we know our

purpose for reading. What kinds of things will you do as you are reading to be sure you're reading the articles critically?" (pages 10–11).

Suggestions for Improvement

- Consider making explicit connections to CCSS-ELA standards when significant reading, writing, or speaking tasks take place, such as when students construct an explanation for why Blue develops different types of cells that the myostatin gene must be "on" in blue's cells, but not his other types of cells, or when students develop an explanatory model for the role of DNA and proteins in the manifestation of Blue's super muscles.
- Consider making explicit references to CCSS mathematics standards when students apply mathematical concepts and skills, such as when students explore the Expected Progeny Differences decision-making tool. These standards can be at the middle school level (making the application of prior mathematics learning explicit).

OVERALL CATEGORY I SCORE: **1** (0, 1, 2, 3)	
Unit Scoring Guide – Category I	
Criteria A-F	
3	At least adequate evidence for all of the unit criteria in the category; extensive evidence for criteria A–C
2	At least some evidence for all unit criteria in Category I (A–F); adequate evidence for criteria A–C
1	Adequate evidence for some criteria in Category I, but inadequate/no evidence for at least one criterion A–C
0	Inadequate (or no) evidence to meet any criteria in Category I (A–F)

CATEGORY II

NGSS INSTRUCTIONAL SUPPORTS

II.A. RELEVANCE AND AUTHENTICITY

II.B. STUDENT IDEAS

II.C. BUILDING PROGRESSIONS

II.D. SCIENTIFIC ACCURACY

II.E. DIFFERENTIATED INSTRUCTION

II.F. TEACHER SUPPORT FOR UNIT COHERENCE

II.G. SCAFFOLDED DIFFERENTIATION OVER TIME

II.A. RELEVANCE AND AUTHENTICITY

Engages students in authentic and meaningful scenarios that reflect the practice of science and engineering as experienced in the real world.

i. Students experience phenomena or design problems as directly as possible (firsthand or through media representations).

ii. Includes suggestions for how to connect instruction to the students' home, neighborhood, community and/or culture as appropriate.

iii. Provides opportunities for students to connect their explanation of a phenomenon and/or their design solution to a problem to questions from their own experience.

Rating for Criterion II.A. Relevance and Authenticity	Adequate *(None, Inadequate, Adequate, Extensive)*

The reviewers found adequate evidence that the materials engage students in authentic and meaningful scenarios that reflect the real world because the lessons focus on examples that most students in the class understand and there are some opportunities for students to experience some of the phenomena firsthand or through videos. However, the driving problem used later in the unit is not defined or experienced concretely for students and students are not prompted to connect questions from their own experiences and culture to their explanations of phenomena.

Students experience most of the phenomena as directly as possible. Related evidence includes:

- Lesson 1: Before students see the phenomenon, they are engaged in categorizing different types of cattle based on their characteristics. Then students are introduced to the anchor phenomenon, “super cattle” through slides (page 15). This juxtaposition allows for easy comparison to normal cattle.
- Lesson 4: Students see images of different types of cells and the teacher is prompted to let students see the cells firsthand if possible. “If you have access to microscopes and slides of different tissues, this would be a great opportunity for students to use microscopes” (page 8).
- Lesson 5: “It sounds like you are talking about the chromosome having two different structures. Let’s look at some other images. Since we were only looking at representations and not real cells, I found two pictures that might give us more information about chromosomes. The pictures were taken with an electron microscope.” Students examine photos and discuss how the structure of chromosomes are related to genes being on and off (pages 6–8)
- Lesson 6: Students observe DNA transcription through an animation since it cannot be observed directly (e.g., page 12).
- Lesson 9: An engaging, relevant problem — global food insecurity — becomes a theme in the later part of the unit. However, this problem isn’t stated as such and isn’t presented to students directly. Instead, the teacher is prompted to, “Say: Is Blue’s mutation a trait that is useful in

some way to addressing global food insecurity?" (page 5) This sentence is the only introduction students have to this problem, and the problem is never made more concrete (e.g., showing data on food insecurity or showing stories of people who don't have enough food). The only data shown are the size of the human and cattle populations (Lessons 1 and 15).

The materials include suggestions for how to connect instruction to the students' home, neighborhood, community, and culture as appropriate. Related evidence includes:

- Lesson 1: Students are shown different pieces of art displaying how people around the world have an interest in cattle, establishing the many different types of cattle around the world. Students observe images of normal cattle and classify each image, prompting a discussion about the different breeds of cattle and the key traits. Students notice and wonder while watching a video to understand the relationship between cattle structures and their function (identifying beef and dairy breeds) and observing images of super cattle (pages 7–16).
- Lesson 1: "Cattle as food sources can be a sensitive subject for students who are or know someone who is a vegetarian or vegan. Additionally, the Hindu culture considers cattle to be a sacred symbol of life. Be sure you observe student reactions and individually check in with students if they appear to be affected by the content of this unit. Inclusion of cattle as draught animals, sport animals, and as a provider of ecological services are also included for students to investigate in this unit" (pages 4 and 7).
- Lesson 1: Students are introduced to the subject of cattle through a story about an international cow art parade. The teacher is told, "Say, This got me wondering about real cattle...so I did a little investigating" (page 7). Students are then asked to predict how many cattle there are on Earth, and then asked what they know about other animal breeds, and then told, "let's learn more about cattle breeds" (page 8). This introduction connects the study of cattle breeds to other ideas that are already familiar to them, including human population numbers and information about dog breeds. However, it isn't clear that students would be authentically motivated to learn about cattle breeds from this introduction.
- Lesson 1: "Understand that some students will have a cultural framework that provides their perspective. Be attentive to that as students begin building understandings of the utility of cattle" (page 12). However, this teacher note is vague; it does not provide examples or specificity.
- Lesson 1: Students are asked to share related phenomenon examples, and peer ideas are recorded publicly (page 18).
- Lesson 2: "Give students 3 minutes to record their related phenomena in their learning logs and to revisit the Super Cattle cards. As students are doing this, prepare a Related Phenomena poster, with this title: 'Organisms I know that are like Blue.' Or 'Organisms I know that are affected by a mutation'" (page 16).
- Lesson 9: "Understand that some students will have a cultural framework that provides their perspective. Be attentive to that as students begin building understandings of the utility of cattle. Encourage students to think about ideas of how cattle can be useful to humans and solve global issues that extend outside of serving as a source of food. (see THIS RESOURCE for

additional info)" (page 5). However, in the lesson there aren't any explicit suggestions for how teachers can assist students in making these connections.

- Lesson 10: There is an unfinished teacher note: "*ATTENDING TO EQUITY: Please be sensitive to students with a" (page 7).
- Lesson 11: A teacher note says, "Be clear when talking about biological sex. Biological sex is more complicated than we think. Gender is not as black and white as we think; instead it is a point on a continuum with infinitesimal gradations. Science is critical to understanding this phenomenon more deeply. To learn more listen to The Biology Of Sex : TED Radio Hour : NPR. You can also read more in this article from Stanford Medicine" (pages 13–14). The teacher is prompted to, "SAY, while we know biological sex is more complex than just X and Y—remember we learned that genes can interact when we investigated the number of genes and the number of proteins? While many traits that we associate for male and female are located on these chromosomes, it is much more complicated. For purposes of our investigation of Blue, we will simplify and use XX to represent female and XY to represent male genders" (page 14). This is helpful but note that it conflates sex and gender (using the terms interchangeably).
- Lesson 14: Student interests are taken into account. "Select to provide a broad range of traits and represent ideas your students have expressed interest in throughout the unit (e.g., particular perspectives, genetic technologies, key traits)" (page 6).
- Lesson 14: The teacher key for the Super Cattle summary points out which breeds have connections to culture that students could learn about.

Suggestions for Improvement

- Consider providing explicit prompts for teachers to cultivate student questions based on their prior experiences in their communities or cultures.
- Lesson 9: Consider providing concrete data or case studies to help make the problem of global food insecurity more apparent and relevant to students.
- Consider providing modifications of some of the discussions and prompts in Lesson 9 to focus on cattle characteristics that provide advantages as work animals, for example, if there are any students in the class that don't eat beef.
- Lesson 11: Consider altering slide 7 and the student handout to zoom in on muscles in the live cows or adding a note that some students may find the pictures of cut muscles uncomfortable when discussing personified animals they've been getting to know.

II.B. STUDENT IDEAS

Provides opportunities for students to express, clarify, justify, interpret, and represent their ideas and respond to peer and teacher feedback orally and/or in written form as appropriate.

Rating for Criterion II.B. Student Ideas	*Extensive* *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that the materials provide students with opportunities to both share their ideas and thinking and respond to feedback on their ideas. The materials provide supports for teachers to act as the expert facilitator and elicit student ideas, students have opportunities to share ideas with peers to improve their own thinking, and some supports for feedback and opportunities for students to reflect on and reply to feedback are provided. However, explicit guidance for teacher feedback is not included in the unit.

Students express, justify, and compare their ideas with peers. For example:

- Lesson 1: Students develop initial models to describe what they think causes the phenomenon. Then the teacher is told, "Direct students to use their Learning Logs A & B to collect similarities and differences between their models. Briefly explain the instructions for Stand Up, Hand Up, Pair Up, and give students about 8 minutes to mingle, comparing models with different partners" (page 16).
- Lesson 1: The class discusses their initial models. "Develop a whole-group record of what we agree on and where we have competing ideas across our initial models. What do we all seem to agree on? What do we disagree on? What are some new ideas that we may want to consider?" (Slide 40). The teacher is told "it is important to highlight areas of disagreement and help students clearly explain their thinking in these areas" (page 17).
- Lesson 2: "Use teacher talk to elicit student thinking (refer to STEM Teaching Tools 30 and 41). Refer them to the scale cards/graphic organizers" (page 11).
- Lesson 2: "When the timer goes off, have students pause where they are in the gallery walk. Instruct them to find one or two people nearest them to talk to. Have each student share an interesting similarity and difference they noticed across the models with their new shoulder partners. Listen for areas of consensus. Set the timer for 5 minutes and ask student groups to volunteer + and Δ items from various student models they observed. Encourage each set of shoulder partners to share an element for discussion" (page 12).
- Lesson 2: "Tell students that the goal of this discussion is to figure out areas of agreement and disagreement in our initial models. Knowing where we agree and disagree will help us figure out how we might want to proceed in figuring out what causes Blue to be 'super'….Furthermore, it is important to highlight areas of disagreement and help students clearly explain their thinking in these areas" (page 14).
- Lesson 4: "Let's start with the idea that we need to know when Blue's cells started changing. Where could we look? Which scales might have the answers we are looking for? Give students a

few minutes to get their ideas down in their learning log. Walk around and take note of the details they are adding. Lead the class in a discussion around the similarities and differences in their drawings. Use this conversation to identify what we agree on and where we need to investigate further by keeping a class record. If no models show the mutation, you might ASK, Where does the mutation show up? Have students add it to their drawings if they haven't included it" (page 7).

- Lesson 4: "SAY, In your learning log, make a prediction that answers the question on the slide. Once everyone has recorded a prediction, have them share with a small group of peers. Ask a student to share their prediction and their reasoning. Ask the class if anyone has a similar prediction and let them share. Ask the class if anyone has a different prediction and let them share" (pages 11–12).
- Lesson 5: "Share drawings of Blue's chromosome 2. What similarities and differences are in your drawings?" (slide 7).
- Lesson 6: Students create initial models of their ideas, then the teacher is told, "When students have completed their models, have them share with others in small groups or pairs. Remind students to use these questions [e.g., 'What similarities and differences are in your models?'] to guide their conversation. Ask a few groups to share some key ideas from their conversation" (page 8).
- Lesson 6: "Say, Use the information provided to make a prediction. Which DNA sequence results in the proteins you see. Record your prediction in your learning log and explain your thinking. Allow students a few minutes to make their prediction and share ideas with an elbow partner" (pages 10–11).
- Lesson 6: "Remind students to also update their Initial Student Model. When students have revised their models, provide them with an opportunity to turn and talk with a partner and then identify remaining questions and gaps in our model" (page 11).
- Lesson 6: "Remember that while you are working together, you each need to record your learning in the task. Monitor students while they work to complete the task" (page 14).
- Lesson 7: "Explain what you think is going on here in your learning log…Have students record questions in their learning logs. Some specific prompts to use with partner groups: Do your drawings explain how mutated myostatin causes more muscle cells?...What has to happen to get more muscle cells? What is missing? What gaps do we need to fill?" (page 6).
- Lesson 7: "Have students open the second model in the task. Have them predict how the change in the shape of myostatin affects the system. Students can draw, screenshot, or print their final products to add to learning logs. Invite students to share their predictions" (page 8).
- Lesson 10: "Allow students time to partner talk, comparing their models. Remind them to track similarities and differences in their learning log and to be ready to share with the whole class" (page 6).
- Lesson 10: The teacher is told, "It is again important to accept all student responses and to encourage students to share their ideas. Furthermore, it is important to highlight areas of disagreement and help students clearly explain their thinking in these areas" (page 6).
- Lesson 11: "Compare models with partners. Direct students to use their Learning Log to collect similarities and differences between their models. Briefly explain the instructions for Stand Up,

Hand Up, Pair Up, and give students about 8 minutes to mingle, comparing models with different partners" (page 11).

- Lesson 11: "Compare models with other groups. Direct students to use their Learning Log to collect similarities and differences between their model calf and others. Briefly explain the instructions and give students about 8 minutes to mingle, comparing calves with different groups" (page 15).
- Lesson 12: "With your partner, compare your thinking. Use Idea Coaching to help each other explain your thinking by asking questions" (Student Task, page 1). Students are also given sentence stems from STEM Teaching Tools, including "I think __ because…", "Evidence that supports my argument is….", and "I think this is supporting evidence because…."
- Lesson 13: "Compare models with partners. Display slide and direct students to use their Learning Log to collect similarities and differences between their models. Allow students time to compare and contrast with multiple partners" (page 7).

Students reflect on their learning. For example:

- Lesson 1: "Recommend that students draw a line under their original model to refer to as they gain new understanding" (page 17).
- Lesson 3: "Add what we have figured out about how one cell becomes two to initial models. Also record what we know about these new cells compared to the original cell and identify where we still have gaps in these models" (page 17).
- Lesson 4: "SAY, Think about the explanations we constructed and the evidence we used to support them. Go back to your predictions in your learning log. Were your predictions about how genes in different types of cells would look accurate? Why or why not?" (page 13).
- Lesson 4: "Revisit your initial thinking in #3 of your learning log. What can you add, remove, change based upon information you have gathered? Revise your model to reflect your new learning in #6 of your Learning Log" (Student Task, page 2).
- Lesson 8: "We have done so much work zooming in to investigate the structures and process inside Blue that this seems like a good place to pause and connect what we have learned in an explanatory model. Have students use the Model Tracker and lesson explanatory models to review what they have figured out in each lesson that should be included in their models" (page 6).

Students have opportunities to receive peer, but not teacher, feedback. For example:

- In several parts of the unit, the teacher collects student models and then hands them back. For example, in Lesson 10: "I will collect these at the end of class and give them back to you tomorrow so you can add them to your learning log" (page 6). Therefore, teachers have opportunities to give individual-level feedback, but suggestions are not provided to the teacher to encourage giving feedback on these student models.
- Lesson 2: Students do a gallery walk of peer models. "Emphasize that everyone should be prepared to compare their own ideas to those they see other people using. Encourage students to linger on the models they see to read the written explanations on them fully. This may mean that each student only gets to a couple of models in the gallery walk, but that is OK. Ask if there

are any questions. Set the timer for 4 minutes and cue students to begin the gallery walk. Students should use a + and Δ system to evaluate classmates' models. + is a strong, quality element of the model. Δ is an element of the model that should be changed or improved upon in some way" (page 12).

- Lesson 8: A teacher strategy note says, "Encourage students to share their models with others to get feedback prior to beginning assessment" (page 6). However, no supports or prompts are given for how a feedback process might be conducted or managed.
- Lesson 10: "Give students 5-8 minutes to construct their models. Walk around the room while students are working and ask probing questions of students who haven't included labels, arrows or written descriptions of how each zoom out space is related" (page 6).
- Lesson 14: "Giving Feedback to Peers: Feedback needs to be specific and actionable. This means it needs to be related to science ideas and it provides your suggestions for improvement. The following are productive examples: 'Your model shows that genetic technology made your super cow. I think you should add detail about what genetic technology was used and how it affected the genes.' 'You said that the trait is only passed on to females. We disagree and suggest reviewing the information about meiosis.' The following are nonproductive examples of feedback that do not help other students improve: 'I like your drawing.' 'Your poster is really pretty.' 'I agree with everything you said'" (Student Task, page 3). Sentence starters are also given, and students are directed to reflect on the feedback. "When you receive feedback, you should do the following: Read it carefully. Ask someone else to help you understand it, if necessary. Decide if you agree or disagree with the feedback and say why you agree or disagree. Revise your work to address the feedback" (Student Task, page 4).
- Lesson 15: In the last task, students are told, "After completing your design, you will present your design for a critique and you will provide feedback for another design" (Student Task, page 2). Students are given guidance and examples of what kind of feedback to give along with guidance for how to react to the feedback, including by revising their work (Student Task, pages 6–7).

Suggestions for Improvement

Consider providing explicit guidance on how the teacher can provide written and oral feedback to students on their thinking and performance in all three dimensions, and how students can reflect and respond to the feedback.

II.C. BUILDING PROGRESSIONS

Identifies and builds on students' prior learning in all three dimensions, including providing the following support to teachers:

i. Explicitly identifying prior student learning expected for all three dimensions

ii. Clearly explaining how the prior learning will be built upon.

Rating for Criterion II.C. Building Progressions	Inadequate *(None, Inadequate, Adequate, Extensive)*

The reviewers found inadequate evidence that the materials identify and build on students' prior learning in all three dimensions. The level of proficiency with which students are expected to enter is outlined for teachers, and the materials provide information regarding building proficiency for some targeted DCI elements. However, learning progressions are not included for SEPs and CCCs.

Related evidence includes:

- "Connections to Middle School NGSS Performance Expectations" are listed in the Front Matter: **MS-LS1-1**, **MS-LS1-3**, **MS-LS3-1**, **MS-LS3-2**, and **MS-LS4-5** (pages 2–3).
- The Storyline document for the unit includes an "Unpacking of the DCIs" which features, "By the 8th grade" section that details the expected prior learning for the DCIs only.
- In the "Where are we going (and not going)," sections of the Teacher Guide, guidance is given to ensure teachers are aware of the prior proficiencies' students should have. However, these are only focused on the progression of learning for the DCIs. For example:
  - Lesson 1: In the lesson front matter, the teacher is told, "Building on middle school learning experiences, it is likely students know Blue's unusual appearance is related to genes/DNA. It is also likely that students will bring an understanding of mutations and artificial selection to their initial explanations of cattle diversity. While students may be familiar with these concepts, it is unlikely at this point in the unit that students are thinking about the underlying mechanisms of meiosis and protein synthesis that drive inheritance of traits and expression of genes. It is also unlikely that they deeply understand the interactions between genes and the environment that play an important role in the expression of genes…. It is not necessary in Lesson 1 that students are able to explain meiosis, protein synthesis, or inheritance as mechanisms underlying their observations. These concepts will be explored in the unit" (page 5).
  - Lesson 2: "Students may come into this unit with different ideas about how animals get such big muscles. They most likely will know that diet and exercise play a large role in how big an animal's muscles get, and may understand the role of mutations in gene variability" (page 5).

  - Lesson 9: "Building on middle school learning experiences, it is likely students know that genetic variation exists among species of organisms. Students are likely to be connecting variation with environmental factors. While students may be familiar with these concepts, it is unlikely at this point in the unit that students are thinking about the underlying mechanisms of meiosis, epigenetics, and genetic technologies that drive inheritance of traits and expression of genes. Students are encouraged [in this lesson] to develop an understanding of the underlying mechanisms that operate at a microscopic scale resulting in observable differences at macroscopic scales" (page 4).
- Lesson 2: "The video uses the phrase 'a gene that doesn't work'. Work with students to connect this concept to mutations. This term is introduced in middle school" (page 8).
- Lesson 2: The lesson prompts teachers to skip redundant information. "If you have previously worked with students to develop investigative questions, show this slide as a reminder—modify for your class agreed upon criteria" (page 20).
- Lesson 11: "Prompting students to consider a pedigree chart and Punnett Square diagram is an opportunity to elicit prior understanding from middle school. Students may or may not have experience with these representations which is fine at this point. You can leverage what they know to move the lesson forward, providing additional practice and scaffolds where needed" (page 11).
- Lesson 11: "This initial modeling sequence is used to scaffold student thinking by building on prior knowledge from middle school. 'In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other. (MS-LS3-2).' This initial modeling practice will help identify gaps in our model that need further investigation—meiosis" (page 13).
- Lesson 12: "The purpose of this discussion is to identify what students know and what we need to figure out together. Listen for the ideas they are bringing from middle school learning experiences—mutations can be harmful, beneficial, or have no effect" (page 7).

Suggestions for Improvement

- Consider providing more explicit guidance regarding student prior proficiency in SEP and CCC elements. This could include adding information to the "Thinking Like a Student" portion of the storyline document, showing prior proficiency needed for each element targeted in the unit.
- Consider providing information about how and when students are expected to develop their understanding of each targeted SEP and CCC element. For example, students may be introduced to the concept behind an SEP in one lesson, use part of the element as a group in another lesson, and then add on another part of the element in a third lesson.

II.D. SCIENTIFIC ACCURACY

Uses scientifically accurate and grade-appropriate scientific information, phenomena, and representations to support students' three-dimensional learning.

Rating for Criterion II.D. Scientific Accuracy	Extensive *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that the materials use scientifically accurate and grade-appropriate scientific information because most of the information is scientifically accurate. Materials use phenomena that are appropriate for high school students and discourse supports along with modeling examples are accurate. The few exceptions are listed below:

- Although the vast majority of the unit deals with this topic accurately, part of Lesson 1 seems to conflate the ideas of purpose and function. This could lead to student misconceptions. For example: "You noticed the horns—what patterns do you see in their shape? — How might that be related to their purpose?" (page 9) This could lead students to think this is *why* horns exist, rather than as a randomly occurring trait that provided reproductive advantages to the animal and therefore was passed on, and that later, humans found a function for the horns and selected for certain types and sizes. This topic is stated accurately on the following page: "You notice horns—what patterns do you see in their shape?--How might that be related to their utility?" (page 10).
- Lesson 2: When the class develops the DQB, the discussion about the definition of investigation questions seems to promote misleading ideas, indicating that in order for a question to be investigable, it must be easily investigable in the classroom by high school students (i.e., the typical science fair formatted questions). However, investigable questions technically means questions unrelated to personal preference (unless it's a sociological study), moral values, or supernatural ideas. Related evidence includes:
    - "What is the difference between these two questions? [1] Do genes cause all of the super cattle traits? [2] How do genes cause super cattle traits? Listen for these ideas: The first one can be answered with yes or no. The second one requires that we investigate genes and traits. SAY, Let's take a good look at these questions and make sure they are written as investigative questions. An investigative question requires us to take action. What 'actions' would we take to investigate a question?" (pages 19–20). However, the two questions discussed here are both testable. This teacher prompt seems to indicate that yes/no questions are not testable and not questions that would "require us to gather information, obtain data, or conduct an investigation."
    - "So it seems like questions that start with what or how fit our ideas of investigative questions" (page 20). The questions discussed here include pairings such as "Are Blue's cells bigger or are there just more of them? How does the mutation cause the changes

to the size and number of Blue's cells?" (page 19). In all cases, the questions are testable; the word at the beginning of the question is not a helpful determinant.

- "Let's see if we can take these questions with variables and rewrite them to be investigative—beginning with how and what. Let's work through an example together, Do genes cause all of the super cattle traits? What are the variables we could investigate that are included in this question? Pause for student responses. Yes, genes and traits are the variables in this question. Now if we begin with how or what and include the same variables, what might the question be?"
- Lesson 12: "Work with students to rewrite questions that can be answered with 'yes' or 'no' as questions that can be investigated, beginning with 'what' or 'how' before adding them to the class DQB" (page 10).

Suggestions for Improvement

Consider rephrasing the discussion about testable/investigable questions in Lesson 2 to instead focus on how to helpfully phrase questions meant to guide a single experiment. Alternately, support could be added to help students distinguish between testable and non-testable questions (e.g., "who would win in a fight: batman or spiderman?"). As mentioned in the *Framework for K–12 Science Education*: "Students also need to recognize the distinction between questions that can be answered empirically and those that are answerable only in other domains of knowledge or human experience."

II.E. DIFFERENTIATED INSTRUCTION

Provides guidance for teachers to support differentiated instruction by including:

i. Supportive ways to access instruction, including appropriate linguistic, visual, and kinesthetic engagement opportunities that are essential for effective science and engineering learning and particularly beneficial for multilingual learners and students with disabilities.

ii. Extra support (e.g., phenomena, representations, tasks) for students who are struggling to meet the targeted expectations.

iii. Extensions for students with high interest or who have already met the performance expectations to develop deeper understanding of the practices, disciplinary core ideas, and crosscutting concepts.

Rating for Criterion II.E. Differentiated Instruction	*Adequate* *(None, Inadequate, Adequate, Extensive)*

The reviewers found adequate evidence that the materials provide guidance for teachers to support differentiated instruction. The unit includes many activities that provide suggested supports for multilingual learners and struggling students. Some supports for students with a high level of interest or students who have already met the PE are included. However, supports focus on class participation and DCI content. Few supports are provided for students to increase their understanding or proficiency with SEPs or CCCs.

Supports are provided to help students with the language in the unit. For example:

- Lesson 1: "Students may refer to images of the cattle as 'cows', 'cattle', bulls or some other word. Whatever they use in their initial ideas is fine….This vocabulary will be introduced to students later in the lesson when students have had an opportunity to conceptualize the terms" (page 7).
- Lesson 1: A teacher side note says, "For ELL learners, provide a framework for understanding the common vocabulary. Front load these terms with students if possible" (page 12). Front loading vocabulary may negatively affect students' initial engagement in concepts in their own language.
- Lesson 3: A teacher note says, "For ELL students, perhaps consider providing a list of mitosis-related vocabulary in the student's native language" (page 9).
- Lesson 7: A teacher note says, "Text 2 in the student task is particularly challenging. Consider using only specific portions of the text that would give students an understanding of the actions of the gene. For example….read the summary together using an annotation strategy. A sample annotation strategy is included using various symbols to help students as they read" (page 7).
- Lesson 10: "Struggling students may find the vocabulary in the task challenging. Consider using the Frayer Model Template to help students understand what is and is not part of the scientific terminology discussed" (page 9).
- Lesson 11: "Students may bring the terms genotype and phenotype to the discussion from middle school. Listen for students to connect these terms in the lesson. It is not necessary to define the terms here if they aren't emerging. As the lesson progresses and there is evidence students have a conceptual understanding, define the terms as a 'shortcut' to explain physical appearance/expression of genes versus the genes they possess" (page 10).

Extension activities are provided for students who are already proficient in the targeted learning or who have high interest. For example:

- Lesson 8: The teacher is given a "Suggestion: Extension idea: Understanding muscle cell development in weight training" (page 6). The reviewers assume that the idea of the extension is to have students read this article if they have already shown proficiency in the targeted learning, but this is not stated.
- Lesson 11: "For advanced students, consider using additional examples to develop their understanding of statistical relationships involved in the inheritance patterns. Students with advanced math knowledge may be able to expand on their Punnett Squares to determine inheritance using quantitative genetic principles" (page 18).

Early in the unit, support is provided for students with disabilities. In Lesson 1, students watch a video, and the teacher is told, "Students with visual impairments may benefit greatly from the printed transcript of the video or the use of closed captioning" (page 13).

Other supports are provided in the unit to meet student needs, including for struggling students. For example:

- Lesson 1: To ensure that all students have a common understanding of cattle as a study organism, students are given the opportunity to do Internet research about cattle. "This quick search will help move students toward productive thinking about cattle traits without being distracted by questions that may arise due to unfamiliarity with cattle as a study organism" (page 12).
- Lesson 3: "Consider providing a graphic organizer for struggling students to use with the mitosis cards that incorporate related vocabulary or description of what is physically taking place" (page 11).
- Lesson 3: "Monitor students as they work and provide support for students who are struggling. Students could also work in small groups if there are students who will need the extra support" (page 12).
- Lesson 4: Several slides are optional supports to be used if needed. For example, "This slide is included if you want to provide more teacher guidance for this portion of the task" (page 9).
- Lesson 6: "If students are struggling with using the codon chart to identify proteins, direct them to this VIDEO for further explanation. Provide them with a basic explanation or additional examples and ensure their understanding before moving on" (page 9).
- Lesson 7: "If students need additional support, consider working through slides 8 & 9 with them" (page 7).
- Lesson 10: "Pair struggling students with those who have models that have (to date in the lessons) been complete and accurate" (page 6).
- Lesson 10: The "Strategies" callout box states, "Consider allowing struggling students to work in small groups to discuss as they complete the task" (page 11).
- Lesson 11: "At this point in the task, you can continue to guide the task OR students can work independently while you monitor their progress and select slides to share with the whole group when needed" (page 17).
- Lesson 11: "Monitor students as they work. Students may need support to calculate probabilities using both Punnett squares. It may help to have them draw all the possibilities and then determine how a mathematical model can represent their drawings" (page 18).
- Lesson 11: "These questions are included in the Modeling Inheritance Task. If students need support, you might want to guide students through the process of developing a Punnett square and determining probabilities for the phenotypes and genotypes" (page 20).
- Lesson 12: "The readings are linked in the document, offer printed materials to students who prefer it" (page 13).

Suggestions for Improvement

- Consider providing additional supports for differentiated instruction related to SEPs and CCCs, such as extra scaffolding related to new CCC ideas.

- To assist students with different reading levels, consider providing alternative text with varying reading levels or additional alternative texts and videos that could allow differentiation for those unable to access the text itself through the suggested differentiation strategies.
- Lesson 4: There is a large cognitive step for students to take between understanding that "The different groups of cells are expressing different genes" and "Different types of cells start developing early in life because different genes are turned on or off" (page 14). Consider adding optional supports for struggling students in case not all students make this leap by themselves right away.

II.F. TEACHER SUPPORT FOR UNIT COHERENCE

Supports teachers in facilitating coherent student learning experiences over time by:

i. Providing strategies for linking student engagement across lessons (e.g. cultivating new student questions at the end of a lesson in a way that leads to future lessons, helping students connect related problems and phenomena across lessons, etc.).

ii. Providing strategies for ensuring student sense-making and/or problem-solving is linked to learning in all three dimensions.

Rating for Criterion II.F. Teacher Support for Unit Coherence	Extensive *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that the materials support teachers in facilitating coherent student learning experiences over time. Although extensive supports are provided to help ensure that the unit storyline is coherent for students, teachers have few supports to help link learning for SEPs or CCCs to the storyline.

The teacher is given supports to understand an overview of what will happen in the unit. For example:

- The Front Matter describes for teachers the overall storyline for students during the unit and each of the two Bends (page 3).
- The Storyline describes the following for each lesson: Lesson Question, Phenomenon/Design Problem, "What we do and figure out," and "How we represent it" (e.g., models created by the class), and Navigation to the next lesson.
- Teachers are given guidance to support linking student engagement across lessons in the Teacher Notes section of each lesson. In addition, each lesson includes summaries of the previous, current, and next lesson. The sections of "Where Are We Going" and "Where we are not going" at the beginning of each lesson are very helpful for teachers to know what is expected and not expected of students for each lesson so teachers can assist students in building knowledge coherently.

- Navigation sections at the beginning and end of each lesson provide teacher guidance for connecting lessons for students.
- Lesson 13: There is some potential confusion, as the teacher notes reference learning from a prior student task before students complete a task in the lesson. "The video is a concise summary of what they have explored on their own in the task. This is an opportunity to note what stood out for them and whether they still have unanswered questions" (page 9).

Support is provided to help students connect their DCI learning to phenomena/problems. However, this kind of support is provided only rarely for high school-level SEP or CCC learning. Related evidence includes:

- Lesson 1: The teacher front matter says, "As students investigate calle [sic] throughout the unit, it should be made clear to them that the purpose of their investigation is related to gathering data and/or information for the causes of how the scale of system components affects inheritance of traits" (page 5).
- Lesson 5: **"**What do we know about how Blue developed muscle cells? What were we able to figure out in our last lesson? Have students record their thinking in their learning logs. Reference the DQB for questions that we can answer in this lesson. In our last lesson we were investigating these 3 types of cells. They have different structures and functions but the same genetic information. Remember Blue has a mutation in his myostatin gene which makes him have more muscle cells, BUT all of his cells contain the mutated myostatin gene. Take out your model component cards and decide what structures and scales we need to investigate to see genes like myostatin turned on and off" (Teacher Guide, page 6).
- Lesson 6: Part of a CCC element (e.g., "*Some systems can only be studied indirectly as they are too small, too fast, or too slow to observe directly*") is used explicitly to connect to student sense-making. "Why do you think this is a video animation—drawings that have been made into a video—and not an actual video of this process? Listen for these ideas: The process may be too fast or too slow to see. The process happens at a tiny scale that can't be seen" (page 12).
- Lesson 8: "What stands out to you about last class? We figured out that the myostatin protein is part of a system inside Blue's cells that functions to regulate muscle growth. What did we decide we need to do now? We are ready to summarize our learning before zooming out" (Teacher Guide, page 5).

Suggestions for Improvement

Consider including additional teacher guidance and strategies for supporting students to clearly see how all of their learning goals in the three dimensions connect to their sense-making and problem solving — especially for SEP and CCC learning.

II.G. SCAFFOLDED DIFFERENTIATION OVER TIME

Provides supports to help students engage in the practices as needed and gradually adjusts supports over time so that students are increasingly responsible for making sense of phenomena and/or designing solutions to problems.

Rating for Criterion II.G. Scaffolded Differentiation Over Time	*Adequate* *(None, Inadequate, Adequate, Extensive)*

The reviewers found adequate evidence that the materials support teachers in helping students engage in the practices as needed and gradually adjust supports over time. Although students engage with several different SEP elements multiple times over the course of the unit, few examples were found of students being supported to develop a high school-level SEP and then being expected to perform more independently later.

Many of the targeted SEP elements are only used one time in the unit, and therefore do not provide opportunities for student progression. Of those that are used more than once, almost all uses include the same amount of scaffolding throughout the unit. For example:

- Targeted element: *Use a model based on evidence to illustrate the relationships between systems or between components of a system.*
  - Lesson 4: Students develop a model to explain cell differentiation and analyze data from microarray data so they can explain why the super cattle develop different types of cells (pages 6–14). Then in Lesson 5, students build a physical model of a chromosome and after learning more information revise the model to include coding and non-coding regions of DNA and methyl groups (pages 8–15). This is the same routine from Lesson 4 and teacher supports to help students build proficiency of this SEP element were not located. In Lesson 12, students again develop a model to explain how a mutation in the MTSN gene affects other body tissues and organs (pages 14–16). This routine is the same as in Lessons 4 and 5. Scaffolds were not located.
  - Lesson 11: Students use the super cattle's family tree to trace the inheritance of the mutated DNA and create a model (pages 9–12). The "Additional Guidance" section of the lesson includes the following information on scaffolding: "Prompting students to consider a pedigree chart and Punnett Square diagram is an opportunity to elicit prior understanding from middle school. Students may or may not have experience with these representations, which is fine at this point. You can leverage what they know to move the lesson forward, providing additional practice and scaffolds where needed. Monitor students as they work, paying attention to the models they develop and the representations they select" (page 11). This was the only mention of scaffolding, and it is located in Lesson 11. Scaffolding for developing a model prior to this was not located.

For one of the targeted SEP elements, students are supported to advance in their learning. There is also a slight reduction in scaffolding because students are expected to find their own sources of information rather than being directed to specific sources. Related evidence includes:

- *Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.*
    - Lesson 12: In the Mutations task, students are supported to gather information from four readings and compare the ideas in the different articles (Student Task, page 2). Later during other readings, the teacher is prompted, “What are some things you will be looking for to know if the information is valid and reliable? Sample response: We will look to see if the website has current information, who is responsible for the information and whether the information is unbiased. A checklist is included in the research task to use as a guide. It is important to work with students to generate criteria to talk through the importance of valid and reliable evidence and information. As students generate a list or criteria, record them on the board. Include any new suggestions for criteria they want added” (page 11). The teacher is also told, “The articles have been specifically chosen to raise questions related to sufficiency of the evidence” (page 13).
    - Lesson 14: Students are asked to find information and evaluate it with given criteria, such as “The ideas are presented without bias” (Student Task, page 2).

Suggestions for Improvement

- Consider modifying the support provided for developing a model in the unit so that students receive additional support or scaffolds earlier on in the unit, and then become increasingly more responsible for independently using modeling to solve problems and explain phenomena by the end of the unit.
- Consider providing students with multiple opportunities to engage in all the targeted SEP elements throughout the unit and adjusting scaffolds for developing and using the SEP elements such that the teacher can clearly see the progress each student is making.

OVERALL CATEGORY II SCORE: **2** (0, 1, 2, 3)	
Unit Scoring Guide – Category II	
Criteria A-G	
3	At least adequate evidence for all criteria in the category; extensive evidence for at least two criteria
2	Some evidence for all criteria in the category and adequate evidence for at least five criteria, including A
1	Adequate evidence for at least three criteria in the category
0	Adequate evidence for no more than two criteria in the category

CATEGORY III

MONITORING NGSS STUDENT PROGRESS

III.A. MONITORING 3D STUDENT PERFORMANCES

III.B. FORMATIVE

III.C. SCORING GUIDANCE

III.D. UNBIASED TASK/ITEMS

III.E. COHERENT ASSESSMENT SYSTEM

III.F. OPPORTUNITY TO LEARN

III.A. MONITORING 3D STUDENT PERFORMANCES

Elicits direct, observable evidence of three-dimensional learning; students are using practices with core ideas and crosscutting concepts to make sense of phenomena and/or to design solutions.

Rating for Criterion III.A. Monitoring 3D Student Performances	*Inadequate* *(None, Inadequate, Adequate, Extensive)*

The reviewers found inadequate evidence that the materials elicit direct, observable evidence of students using practices with DCIs and CCCs to make sense of phenomena and design solutions. Observable student artifacts are routinely developed throughout the unit and are focused on students making sense of phenomena. However, there is a pattern of significant mismatches between SEPs and CCCs that are intended to be assessed and the evidence those SEPs and CCCs are required to respond to the tasks.

Related evidence includes:

- Student artifacts are collected throughout the unit. For example, in Lesson 3 the teacher is told, “Remind them to individually record their thinking so you have evidence of their individual learning” (page 12).
- A scenario is used that requires application of student understanding. In the Lesson 8 assessment, students are given this prompt, “If we found a way to repair a single cell with the defective MSTN gene in a 2-month old calf, could we cure double muscles by repairing that single cell? Explain” (Student Task, page 3).
- Most student tasks only use one high school-level dimension (DCIs). Students are not asked to develop or use high school-level SEPs and CCCs in many cases. For example, in the Lesson 6 Protein Synthesis task, the student prompt that uses the highest-level SEP understanding is “Do you think all mutations will change the shape of a protein? Why or why not? (Use the codon chart as evidence to support your answer.)?” The teacher answer key says the answer is “No - some mutations do not affect the protein that is formed, so you would never know it was mutated. An example is AAA and AAG. Both will code for Lysine.” This response only requires a Grade 3–5-level SEP element: *Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem*.
- Some high school-level student artifacts are generated in the unit (see evidence for student use of individual elements under Criterion I.B):
    - Lesson 6: “Students develop and use multiple types of models to provide a mechanistic account to simulate information flows from DNA to protein formation” (pages 6–7).
        - SEP: **Developing and Using Models**: *Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, ~~and move flexibly between model types based on merits and limitations~~.*

        - CCC: **Systems and System Models**: *Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions — including energy, matter, and information flows — within and between systems at different scales.*
        - DCI: **LS1.A: Structure and Function**: *All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells.*
    - Lesson 11: Students use various models, including a physical model to show DNA movement between parent and child.
        - SEP: **Developing and Using Models**: *Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, ~~and move flexibly between model types based on merits and limitations~~.*
        - CCC: **Systems and System Models**: *Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions — including energy, matter, and information flows — within and between systems at different scales.*
        - DCI: **LS1.B: Growth and Development of Organisms**: *The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells.*
    - Lesson 12: Students model the effects of genetic mutations on muscles and the full organism. The teacher is also prompted, "Ask, What scales did we see the MSTN mutation in this lesson? Feel free to use your model component cards. Listen for these ideas: We saw the MSTN gene in many other organisms so that takes us to populations and communities. Ask, What can we add to our timeline to explain Bue[sic] and his mutation? Listen for these ideas: We know Blue's mutation has harmful effects on his body" (page 16).
        - SEP: **Developing and Using Models**: *Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.*
        - CCC: **Cause and Effect:** *Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.*
        - DCI: **LS3.B: Variation of Traits***: In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited.*

- Lesson 14: "Students integrate and evaluate information about how different processes in living systems cause normal cattle and super cattle to be the same and different" (Teacher Guide, page 5).
  - SEP: **Obtaining, Evaluating, and Communicating Information**: *Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.*
  - CCC: **Cause and Effect**: *Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.*
  - DCI: **LS1.A Structure and Function**: *All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells.*

Suggestions for Improvement

Consider providing students opportunities to develop artifacts that showcase understanding of all targeted high school-level learning goals.

III.B. FORMATIVE

Embeds formative assessment processes throughout that evaluate student learning to inform instruction.

Rating for Criterion III.B. Formative	Adequate *(None, Inadequate, Adequate, Extensive)*

The reviewers found adequate evidence that the materials embed formative assessment processes throughout that evaluate student learning and inform instruction because each lesson provides identified formative assessment opportunities for the named lesson-level objectives. The informal assessment opportunities frequently provide guidance on how to shift instruction based on student understanding, and the formal assessment opportunities provide extensive guidance on what to look/listen for in student responses. However, these formal opportunities do not include guidance on how the teacher could shift instruction based on student understanding. In addition, most formative assessment guidance focuses solely on DCI-related student performance.

Related evidence includes:

- Assessment Overview: "Assessing every LPE listed can be logistically difficult. Strategically picking which LPEs to assess and how to provide timely and informative feedback to students on their progress toward meeting these is left to the teacher's discretion" (page 1).
- The Assessment Overview document provides a table showing good opportunities "for assessing student progress toward meeting" the LPEs (e.g., page 2). For example:
    - Lesson 1: The table suggests: "Question 2 in the Student Learning Log can be used to formatively assess asking questions and understanding of inheritance and variation of traits."
    - Lesson 5: The table suggests: "Use the modeling sections in the Student Learning Log and the lesson task to monitor students as they develop and revise their model throughout the lesson as they gather additional evidence that explains chromosome structure."
    - Lesson 12: The table suggests: "To conclude their research, students develop a model to explain how a mutation in the MSTN gene affects other body tissues and organs. Use the model in the Effects of Double Muscles task as a formative assessment opportunity."
- Assessment guidance is provided in each lesson, although most guidance is focused on DCIs and student models, and teacher answer keys for student models focus solely on the factual content of the models rather than on the features of high school-level modeling. Related evidence includes:
    - Lesson 1: "Students' initial models can be used to formally assess both student use of models and their understanding of genetic inheritance and/or the structure and functions of cattle traits. Student questions recorded in their Learning Log and posted to the DQB can also be used as formative assessment" (page 6).
    - Lesson 1: "To quickly assess student understanding, visit groups while they are working to discuss their classification choices" (page 16). Suggestions for how teachers could shift instruction based on student understanding were not located.
    - Lesson 2: "Students' initial models can be used to formatively assess both student use of models and their understanding of genetic inheritance, mutations, and/or the structure and function of cattle traits" (page 5).
    - Lesson 2: "Give students 5–8 minutes to construct their models. Walk around the room while students are working and ask probing questions of students who haven't included labels, arrows or written descriptions of how each zoom in space is related" (pages 9 and 11).
    - Lesson 2: "Teachers can review student time-line models as a group before moving onto the scale model. To evaluate student work, look for related vocabulary in student responses. These can be turned in to be assessed and/or referred to in later lessons" (page 14). This teacher note seems to indicate that correct use of vocabulary is the ultimate goal, whereas vocabulary only relates to DCIs (not SEPs or CCCs) and is not a strong indicator of student understanding of the DCIs.
    - Lesson 3: "Use the modeling sections in the Student Learning Logs to monitor students as they develop and revise their model to explain mitosis. This lesson includes two

embedded tasks. The Analysis Questions in the Cell Cycle Task and the Mitosis and Blue Task can be used as formative assessment. The temporal and spatial models can also be used to monitor the modeling practice and the development of mitosis as a key idea to explain Blue at different scales" (page 5).

- Lesson 3: "Use the Analysis Questions in the Cell Cycle Task as formative assessment to monitor student progress toward this target" (Teacher Guide, page 10).
- Lesson 4: "Use the modeling sections in the Student Learning Logs to monitor students as they develop and revise their model to explain cell differentiation. This lesson includes an embedded task and the Analysis Questions can be used as formative assessment. The temporal and spatial models can also be used to monitor the modeling practice and the development of differentiation as a key idea to explain Blue at different scales" (page 5).
- Lesson 5: "Use the modeling sections in the Student Learning Log and the lesson task to monitor students as they develop and revise their model throughout the lesson as they gather additional evidence that explains chromosome structure. The temporal and spatial models can also be used to monitor the modeling practice and the development of chromosome structure as a key idea to explain Blue at different scales" (pages 4–5).
- Lesson 6: "Use the modeling sections in the Student Learning Logs and lesson tasks to monitor students as they develop and revise their model to explain protein synthesis. Use the Ask Questions section of the Learning Log and the Analysis Questions to monitor the types of questions students are asking about models. The temporal and spatial models can also be used to monitor the modeling practice and the development of protein synthesis as a key idea to explain Blue at different scales" (page 5).
- Lesson 6: As students complete their initial models, the teacher is told, "To assess student models, you can use a simple strategy, such as a +/Δ tool. Any ideas that are strong and clearly connected receive a +. Any areas that need to be further developed or are lacking a clear connection to material should receive a Δ. Students then know that their model needs additional attention before moving onto the next section of the lesson" (page 8). Note that this support only seems to focus on DCI-related understanding.
- Lesson 6: "If students are struggling with using the codon chart to identify proteins, direct them to this VIDEO for further explanation. Provide them with a basic explanation or additional examples and ensure their understanding before moving on" (page 9).
- Lesson 7: "Use the modeling sections in the Student Learning Log to monitor students as they develop and revise their model to explain how myostatin affects muscle growth. This lesson includes an embedded task and the Analysis Questions can be used as formative assessment. The temporal and spatial models can also be used to monitor the modeling practice and the development of cell regulation as a key idea to explain Blue at different scales" (page 4).

- Lesson 7: "The Student Task, Investigating Myostatin can be used as a formative assessment" (Teacher Guide, page 7). Suggestions for how teachers could shift instruction based on student understanding were not located.
- Lesson 8: "This lesson begins to set up the final unit project. Students' initial claim-evidence research can be used to formatively assess their understanding of the usefulness of the variation of traits among cattle. Student questions recorded in their Learning Log and posted to the DQB can also be used as formative assessment" (page 4).
- Lesson 10: "The modeling sections of the learning log can be used to monitor students' use of a model to explain meiosis. This lesson includes an embedded task and the Summarize Meiosis questions can be used as formative assessment for the learning target. The temporal and spatial models of Blue can also be used to monitor the modeling practice and the development of meiosis as a key idea to explain Blue at different scales" (page 5).
- Lesson 11: "Throughout the task in this lesson, students use multiple models to predict how the MSTN gene is inherited in Blue's family. Use the modeling sections of the task as formative assessment. Additionally, question 30 in the task asks students to evaluate the three models. The temporal and spatial models of Blue can also be used to monitor the modeling practice and the development of inheritance as a key idea to explain Blue at different scales" (page 5).
- Lesson 11: "Remember to collect initial models as a pre-assessment opportunity at the end of class. (See assessment guidance section of the Teacher Guide for more information.)" (page 11).
- Lesson 12: "The three tasks, Mutations, Double Muscle Research, and Double Muscle Effects on Organisms provide formative assessment opportunities. The temporal and spatial models can also be used to monitor the modeling practice and the development of mutations as a key idea to explain Blue at different scales" (page 5).
- Lesson 12: "To conclude their research, students develop a model to explain how a mutation in the MSTN gene affects other body tissues and organs. Use the model in the Effects of Double Muscles task as a formative assessment opportunity" (Teacher Guide, page 8). Suggestions for how teachers could shift instruction based on student understanding were not located.
- Lesson 13: "The student Learning Logs and the Analysis Questions in the student task can be used as formative assessment opportunities. The temporal and spatial models of Blue can also be used to monitor the modeling practice and the development of epigenetics as a key idea to explain gene expression at different scales" (page 4).
- Lesson 13: "Give students 5-10 minutes to construct their models. Walk around the room while students are working and ask probing questions of students who haven't included their labels, arrows, or written descriptions of how the inside and outside of the cow are genetically related" (page 7).

- Lesson 14: As students revise their models a final time, the teacher is told, “Allow students time to work through the task. Monitor students as they work and provide support where needed” (page 8).

Suggestions for Improvement

- For each formative assessment opportunity, consider identifying what the targeted element is for each dimension being assessed.
- Consider adding in support for how teachers could modify instruction if students do not show the expected level of understanding or proficiency in any one of the three targeted dimensions.
- Assessment Opportunities are described at the beginning of each lesson. It could be helpful to teachers to more consistently include a small note reminding them of assessment opportunities where they arise during the activities themselves. One such note appears in Lesson 11, page 11.

III.C. SCORING GUIDANCE

Includes aligned rubrics and scoring guidelines that provide guidance for interpreting student performance along the three dimensions to support teachers in (a) planning instruction and (b) providing ongoing feedback to students.

Rating for Criterion III.C. Scoring Guidance	*Inadequate* *(None, Inadequate, Adequate, Extensive)*

The reviewers found inadequate evidence that the materials include an aligned rubric and scoring guidelines that help the educator interpret student performance. Expected student answers are usually present in the teacher materials, and assessment targets are present. However, the example student answers focus primarily on DCI-related information. Scoring guidance for high school-level SEPs and CCCs is not provided. There are also some mismatches between assessment targets and performance indicators.

Related evidence includes:

- LPEs are listed for each lesson, and the Assessments Overview document lists the assessments that could be used to monitor student progress toward each, therefore matching assessments to specific assessment targets. However, in informal assessment opportunities it is often difficult to determine which element is targeted. The targeted three dimensions are listed at the beginning of each lesson rather than together with the scoring guidance for the task identified in that lesson. For informal assessment opportunities, teacher notes sometimes call out a specific element that is intended to be assessed, but most of the time the teacher supports focus solely on the category level descriptors for the DCIs (e.g., “Variation of Traits”).

- Answer keys are included for student tasks, except in Lesson 13 and the final task in Lesson 15. Note also that the Teacher Answer Key for Lesson 15 Student Task EPDs is missing the key to most questions. The answer keys present, however, focus on DCI-related information and only include exemplar responses rather than multiple levels of student responses. For example, the Teacher Key for the Spatial Model Zoomed In only describes the factual content of the models rather than the structure of the models (to help diagnose students who may have trouble modeling). As a minor note, the teacher answer key for the Lesson 4 student task may be confusing because the correct answers are shown in black whereas the rest of the answer key shows the correct answers in red, so teachers may think the red answers are correct.
- Student work samples are not included in the unit.
- Lesson 1: "To assess student models, you can use a simple strategy, such as a +/Δ tool. Any ideas that are strong and clearly connected receive a +. Any areas that need to be further developed or are lacking a clear connection to material should receive a Δ. Students then know that their model needs additional attention before moving onto the next lesson" (pages 16–17).
- Lesson 3: A CER writing rubric is provided that describes multiple levels of student proficiency of part of a high school-level element (performance of a full high school element is not described). The rubric does not include DCI- or CCC-related descriptors (page 16).
- Lesson 6: As students complete their initial models, the teacher is told, "To assess student models, you can use a simple strategy, such as a +/Δ tool. Any ideas that are strong and clearly connected receive a +. Any areas that need to be further developed or are lacking a clear connection to material should receive a Δ. Students then know that their model needs additional attention before moving onto the next section of the lesson" (page 8). Note that this support only seems to focus on DCI-related understanding.
- Lesson 10: An optional assessment tool is provided. "Consider using an assessment rubric for the exit ticket. This will give you an understanding of where students are with their understanding before moving into inheritance patterns in the next lesson" (page 14). However, no scoring guidance is provided in this tool. Instead, it seems to be a scaffold for student reflection on their own performance, without any criteria related to a specific task.
- Lesson 14: A rubric is included, and it claims to measure a three-dimensional performance. However, the performance indicators only describe high school-level DCI performance (i.e., the content of what students communicate). Specifications of high school-level SEP and CCC elements are not included. For example, although the claimed three-dimensional assessment target says "compare, integrate, and evaluate sources of information," the rubric only asks students to "thoroughly and clearly state the main points and precise details that are accurately focused on the topic."
- Lesson 15: A **Systems and System Models** CCC element is claimed, and students are given some prompts that might show understanding. "What are all of the inputs and outputs of a breeding system that includes Blue?" "What are the boundaries of a breeding system that includes Blue? Explain why you identified those boundaries. Think about the largest scale that helps explain all of the factors that need to be considered when thinking about breeding programs" (Student Task, page 3) However, the Teacher Answer Key only says, "Due to Blue's myostatin mutation, it is important to strongly consider complementary breeds in developing a system including him"

(Teacher Key, page 4), so the answer key does not align with student expectations as it does not include high school-level CCC details.

Suggestions for Improvement

- Consider providing scoring guidelines for a range of student responses for all three dimensions that show teachers how they can interpret student progress. For example, including descriptions for what a developing vs. proficient vs. advanced level of performance looks like for all three of the targeted dimensions could help support the teacher in understanding and interpreting student responses.
- Example student models would be very helpful to include. These could show teachers what level and sophistication of models students are expected to produce at the high school level and how their models are expected to change as students become more proficient with modeling.
- Consider providing clearly stated assessment targets for the different assessment opportunities in each lesson, for all dimensions being assessed and their use together, to ensure teachers can accurately monitor student performance for each learning goal.

III.D. UNBIASED TASK/ITEMS

Assesses student proficiency using methods, vocabulary, representations, and examples that are accessible and unbiased for all students.

Rating for Criterion III.D. Unbiased Task/Items	*Extensive* *(None, Inadequate, Adequate, Extensive)*

The reviewers found extensive evidence that the materials assess student proficiency using accessible and unbiased methods, vocabulary, representations, and examples. The assessment opportunities in the unit use clear and accessible language and representations, and students regularly have the opportunity to use different modalities to show their understanding.

Related evidence includes:

- Students are supported to understand and successfully complete tasks. For example:
  - Lesson 1: To ensure that all students have a common understanding of cattle as a study organism, students are given the opportunity to do Internet research about cattle. “This quick search will help move students toward productive thinking about cattle traits without being distracted by questions that may arise due to unfamiliarity with cattle as a study organism” (page 12).

  - Students are often scaffolded in modeling assessment tasks so they can successfully show their DCI understanding (note that the scaffolding only relates to DCI content of models). Related evidence includes:
    - In multiple lessons, students have the opportunity to first help develop a class consensus model and then to go on and develop a related model individually that is used for assessment.
    - In multiple lessons, students have the opportunity to first decide on (DCI focused) model criteria as a group to ensure the required model components are included in their individual models.
- Tasks are presented in multiple modalities. For example, in Lesson 2, the task is presented through a slide, a student handout, and oral teacher directions. "Cue students to create their initial model by representing the events that have been used to create Blue over time. Encourage students to add events that they know must be happening even though they weren't observable in the video" (page 9).
- Student work in multiple modalities. For example:
  - Throughout the unit, students develop and revise models and are encouraged to use drawing, words, and arrows to explain their thinking (e.g., Lesson 2, page 11).
  - Lesson 5: Students build a physical model of Blue's chromosome 2. They compare and evaluate their models. (Teacher Guide, page 11).
  - Lesson 7: Students investigate myostatin by examining graphics and showcasing understanding through completion of interactive computer model (Teacher Guide, page 7).

Suggestions for Improvement
N/A

III.E. COHERENT ASSESSMENT SYSTEM	
Includes pre-, formative, summative, and self-assessment measures that assess three-dimensional learning.	
Rating for Criterion III.E. Coherent Assessment System	*Adequate* *(None, Inadequate, Adequate, Extensive)*

The reviewers found adequate evidence that the materials include pre-, formative, summative, and self-assessment measures that assess three-dimensional learning. Assessment guidance is given to teachers and opportunities for all four types of assessment are present. However, each summative assessment opportunity is optional, and assessments do not closely match student learning goals for SEPs or CCCs.

The Assessment Overview document provides a table showing good opportunities "for assessing student progress toward meeting" the LPEs through formative and summative assessment. The one mention of summative assessment is for Lesson 8 (about halfway through the unit): "This lesson is the summative assessment for lessons 1–7. Students should review their Progress Tracker and notes from the lessons to answer questions and draw their explanatory models to demonstrate their understanding of the performance expectations up to this point in the unit" (page 3).

Pre-Assessment:

- Lesson 1: "Remember to collect initial models as a pre-assessment opportunity at the end of class. Model tracker will be returned to students as they develop new models. Recommend that students draw a line under their original model to refer to as they gain new understanding. (See assessment guidance section of the Teacher Guide for more information)" (page 17).
- Lesson 2: "The lesson is designed to elicit and leverage student understanding from middle school related to Structure and Function, Growth and Development, Inheritance of Traits, Variation of Traits, and artificial selection" (page 5).
- Lesson 11: "Prompting students to consider a pedigree chart and Punnett Square diagram is an opportunity to elicit prior understanding from middle school. Students may or may not have experience with these representations which is fine at this point. You can leverage what they know to move the lesson forward, providing additional practice and scaffolds where needed" (page 11).

Formative Assessment: See related evidence under Criterion III.B.

Self-Assessment:

- Students are given a Self-Evaluation form, although it mostly focuses on students' discourse activities (e.g., whether or not the student invites peers to share their thinking). Regarding their science learning, students are asked to, "Answer the Lesson Question," record new questions, and record ideas for next steps.
- Lesson 10: An optional assessment tool is provided. "Consider using an assessment rubric for the exit ticket. This will give you an understanding of where students are with their understanding before moving into inheritance patterns in the next lesson" (page 14). However, no scoring guidance is provided in this tool. Instead, it seems to be a scaffold for student reflection on their own performance, without any criteria related to a specific task.

Summative Assessment:

- Lesson 8: "This lesson is the summative assessment for lessons 1–7. Students should review their Model Trackers and notes from the lessons to answer questions and draw their explanatory models to demonstrate their understanding of the performance expectations up to this point in the unit" (pages 3–4). A teacher note about this assessment says, "It is up to the teacher to determine if you want students to use their incremental model trackers on the assessment or not, but they should refer to it as well as their notes in this discussion to review the previous lessons" (page 5). Then another teacher note says, "Allow students to use their model tracker and lesson explanatory models to complete the assessment" (page 6). A third teacher note says, "If your students have been completing this as you go through the lessons, you may only need to give them some time to discuss and review before the assessment. If they have not been filling it out as they go, completing the entire packet is a great way to review" (page 6). In this case, the task would not be used as summative assessment.

- Lesson 8: Another assessment idea is given as a side note to the teacher. "To further assess student understanding of DM organisms, provide students with a list of other organisms in which double muscling has been seen. Have students complete the worksheet to determine if all double muscling is a result of the same cellular mechanisms."
- Lesson 14: "The Student Super Cattle Summary provides a student artifact that can be used as formative or summative assessment. In this lesson, students construct their final model revisions to the on-going temporal and spatial models of Blue which can also be used as assessments" (page 4). When this task comes up in the lesson, the teacher is told, "Handout the Student Task: Normal & Super Cattle Summary. This task can be used to assess student learning. Consider whether to have students work individually or collaboratively. Remind students to make use of the Model Component Cards" (page 8).
- Lesson 15: The last task of the unit is framed as formative, rather than summative, assessment. "The design task is an opportunity to formatively assess students related to the targets" (page 5).

Suggestions for Improvement

Consider providing more opportunities for student assessment related to high school-level SEP and CCC elements.

III.F. OPPORTUNITY TO LEARN

Provides multiple opportunities for students to demonstrate performance of practices connected with their understanding of disciplinary core ideas and crosscutting concepts and receive feedback.

Rating for Criterion III.F. Opportunity to Learn	*Adequate* *(None, Inadequate, Adequate, Extensive)*

The reviewers found adequate evidence that the materials provide multiple opportunities for students to demonstrate performance of practices connected with their understanding of DCIs and CCCs because students have iterative opportunities to get feedback and improve on their DCI understanding and their performance in one of the claimed SEP elements. However, these kinds of opportunities are not provided for the other targeted learning goals, and students do not have explicit opportunities to receive feedback from the teacher.

- Students create initial models in Lesson 1 to explain what causes super cattle to have unique traits. Students revisit these models in many lessons to demonstrate and document how their DCI learning has changed over time and receive peer feedback along the way. For example:
  - Lesson 1: "To assess student models, you can use a simple strategy, such as a +/Δ tool. Any ideas that are strong and clearly connected receive a +. Any areas that need to be further developed or are lacking a clear connection to material should receive a Δ. Students then know that their model needs additional attention before moving onto the next lesson" (pages 16–17).
  - Lesson 2: Students do a gallery walk of peer models. "Emphasize that everyone should be prepared to compare their own ideas to those they see other people using. Encourage students to linger on the models they see to read the written explanations on them fully. This may mean that each student only gets to a couple of models in the gallery walk, but that is OK. Ask if there are any questions. Set the timer for 4 minutes and cue students to begin the gallery walk. Students should use a + and Δ system to evaluate classmates' models. + is a strong, quality element of the model. Δ is an element of the model that should be changed or improved upon in some way" (page 12).
  - Lesson 4: Students develop initial models of what mutated cells could look like (page 6).
  - Lesson 5: Students build a physical model of Blue's chromosome 2. They compare and evaluate their models (page 11).
  - Lesson 7: Students investigate myostatin by examining graphics and showcasing understanding through completion of interactive model (page 7).
  - Lesson 8: "Encourage students to share their models with others to get feedback prior to beginning assessment" (Teacher Guide, page 6).
  - Lesson 10: "Give students 5–8 minutes to construct their models. Walk around the room while students are working and ask probing questions of students who haven't included labels, arrows or written descriptions of how each zoom out space is related" (page 6).
  - Lesson 14: Students revisit their initial pair of models in Lesson 1 and document what they have learned about super cattle compared to normal cattle (page 7).
  - Lesson 14: "Giving Feedback to Peers: Feedback needs to be specific and actionable. This means it needs to be related to science ideas and it provides your suggestions for improvement. The following are productive examples: 'Your model shows that genetic technology made your super cow. I think you should add detail about what genetic technology was used and how it affected the genes.' 'You said that the trait is only passed on to females. We disagree and suggest reviewing the information about meiosis.' The following are nonproductive examples of feedback that do not help other students improve: 'I like your drawing.' 'Your poster is really pretty.' 'I agree with everything you said'" (Student Task, page 3). Sentence starters are also given, and students are directed to reflect on the feedback. "When you receive feedback, you

should do the following: Read it carefully. Ask someone else to help you understand it, if necessary. Decide if you agree or disagree with the feedback and say why you agree or disagree. Revise your work to address the feedback" (Student Task, page 4).

- Lesson 15: In the last lesson focused on an engineering design task, students are told, "After completing your design, you will present your design for a critique and you will provide feedback for another design" (Student Task, page 2). However, as this is the very last task of the last lesson, students don't have an opportunity to apply this feedback before a summative assessment.

Suggestions for Improvement

For all focal learning goals in the unit, consider including explicit opportunities for students to demonstrate understanding, then receive feedback from the teacher, then revise and demonstrate new understanding.

OVERALL CATEGORY III SCORE: **1** (0, 1, 2, 3)	
Unit Scoring Guide – Category III	
Criteria A-F	
3	At least adequate evidence for all criteria in the category; extensive evidence for at least one criterion
2	Some evidence for all criteria in the category and adequate evidence for at least five criteria, including A
1	Adequate evidence for at least three criteria in the category
0	Adequate evidence for no more than two criteria in the category

SCORING GUIDES FOR EACH CATEGORY

UNIT SCORING GUIDE – CATEGORY I (CRITERIA A-F)

UNIT SCORING GUIDE – CATEGORY II (CRITERIA A-G)

UNIT SCORING GUIDE – CATEGORY III (CRITERIA A-F)

OVERALL SCORING GUIDE

Scoring Guides for Each Category

Unit Scoring Guide – Category I (Criteria A-F)	
3	At least adequate evidence for all of the unit criteria in the category; extensive evidence for criteria A–C
2	At least some evidence for all unit criteria in Category I (A–F); adequate evidence for criteria A–C
1	Adequate evidence for some criteria in Category I, but inadequate/no evidence for at least one criterion A–C
0	Inadequate (or no) evidence to meet any criteria in Category I (A–F)

Unit Scoring Guide – Category II (Criteria A-G)	
3	At least adequate evidence for all criteria in the category; extensive evidence for at least two criteria
2	Some evidence for all criteria in the category and adequate evidence for at least five criteria, including A
1	Adequate evidence for at least three criteria in the category
0	Adequate evidence for no more than two criteria in the category

Unit Scoring Guide – Category III (Criteria A-F)	
3	At least adequate evidence for all criteria in the category; extensive evidence for at least one criterion
2	Some evidence for all criteria in the category and adequate evidence for at least five criteria, including A
1	Adequate evidence for at least three criteria in the category
0	Adequate evidence for no more than two criteria in the category

OVERALL SCORING GUIDE	
E	**Example of high quality NGSS design—**High quality design for the NGSS across all three categories of the rubric; a lesson or unit with this rating will still need adjustments for a specific classroom, but the support is there to make this possible; exemplifies most criteria across Categories I, II, & III of the rubric. (total score ~8–9)
E/I	**Example of high quality NGSS design if Improved—**Adequate design for the NGSS, but would benefit from some improvement in one or more categories; most criteria have at least adequate evidence (total score ~6–7)
R	**Revision needed—**Partially designed for the NGSS, but needs significant revision in one or more categories (total ~3–5)
N	**Not ready to review**—Not designed for the NGSS; does not meet criteria (total 0–2)