Genetics unit lesson plan for the Next Generation Science Standards

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Abstract
In 2015, Iowa’s adoption of the Next Generation Science Standards (NGSS) compelled the Waterloo Community Schools to set a goal of complete alignment to those standards by the 2018-2019 school year. In order to prepare for this transition, I chose to focus my creative component on the development and implementation of a NGSS aligned unit on Genetics for a sophomore level biology course. The unit focused on the Performance Expectation (PE) HS-LS3-3: Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population and incorporated all three dimensions of the NGSS: Science and Engineering Practice (SEP) of analyzing and interpreting data, the Disciplinary Core Idea (DCI) of variation of traits, and the Crosscutting Concept (CC) of scale, proportion, and quantity. The Understanding by Design (UbD) method of backwards lesson planning was utilized in the creation of the unit. Various methods of assessment were dispersed throughout the unit including a preassessment, numerous formative assessments, a summative assessment project and a summative traditional assessment. Upon completion of the implementation of the unit, the EQUiP rubric was utilized to evaluate the quality of the unit and its alignment to the NGSS. Although there was no significant difference between pre and post assessment scores, student enjoyment of the class activities was evident and the student engagement level was higher than in previous, non-NGSS style lesson plans.
GENETICS UNIT LESSON PLAN FOR THE NEXT GENERATION SCIENCE
STANDARDS

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In 2015, Iowa’s adoption of the Next Generation Science Standards (NGSS) compelled the Waterloo Community Schools to set a goal of complete alignment to those standards by the 2018-2019 school year. In order to prepare for this transition, I chose to focus my creative component on the development and implementation of a NGSS aligned unit on Genetics for a sophomore level biology course. The unit focused on the Performance Expectation (PE) HS-LS3-3: *Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population* and incorporated all three dimensions of the NGSS: Science and Engineering Practice (SEP) of analyzing and interpreting data, the Disciplinary Core Idea (DCI) of variation of traits, and the Crosscutting Concept (CC) of scale, proportion, and quantity. The Understanding by Design (UbD) method of backwards lesson planning was utilized in the creation of the unit. Various methods of assessment were dispersed throughout the unit including a pre-assessment, numerous formative assessments, a summative assessment project and a summative traditional assessment. Upon completion of the implementation of the unit, the EQUiP rubric was utilized to evaluate the quality of the unit and it’s alignment to the NGSS. Although there was no significant difference between pre and post assessment scores, student enjoyment of the class activities was evident and the student engagement level was higher than in previous, non-NGSS style lesson plans.
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CHAPTER 1
INTRODUCTION

For thousands of years, people have understood that children often resemble their parents. However, it was not until the 20th century that humans could scientifically explain how that occurred. Since the discovery of DNA, the field of genetics has developed very rapidly, creating opportunities for improvements to our everyday lives. Advancements in genetics have the potential to assist in the fields of health and medicine, criminology, and genealogy, but could also pose a threat to our privacy. Yet for a topic that has the potential to affect many human lives, it is a surprisingly misunderstood and mysterious topic to the general population.

The Carnegie Foundation for the Advancement of Teaching, is a collection of U.S. scholars, practitioners, and designers tasked with the assignment of solving issues in science to improve teaching and learning (Carnegie Foundation, n.d.). In 2009, the foundation members established that in order for the nation to compete globally, prosper economically, and maintain the ideals of the American dream, our workforce must have a solid foundation of math and science knowledge (Carnegie Foundation, n.d.). Unfortunately, the current system of science and mathematics education is failing to not only create a new generation of innovative scientists and engineers, but it also is unsuccessful in providing every American citizen with the basic knowledge to make everyday decisions (Next Generation Science Standards (NGSS), n.d.-g).
The Organization for Economic Cooperation and Development (OECD) is an assembly of 35 countries with the goal of stimulating policies that will improve the economic and social health of people all over the world (OECD, n.d.). The OECD collects data and research on many aspects of a country’s well-being and issues reports comparing countries in various areas, one of those areas being education. According to the 2012 OECD reports, the U.S. ranked 23rd in science and 30th in math out of 65 countries. Three years previously, the OECD ranked the U.S. 20th in science and 25th in math (OECD, 2010). Also in 2012, 54% of high school graduates did not meet the ACT’s college readiness benchmark in math and 69% did not meet the readiness benchmark in science. In 2011, the U.S. ranked 23rd in high school graduation rates (NGSS, n.d.-g).

The U.S. economy reflects this decline in science and math education. For more than half a century, U.S. science-based invention fueled our economy and produced jobs which afforded U.S. citizens a higher standard of living and elevated the U.S. into a political and economic force in the world (Atkinson & Mayo, 2010). From 2008-2015, foreign competitors rather than U.S. companies, filed for more than half of the applications for patents for technological products (U.S. Patents and Trademark Office, 2015). Additionally, China has become number one in exporting high-tech products while the export rate of high-tech goods in the U.S. continues to deteriorate (NGSS, n.d.-g). Not only is the U.S. unable to produce high-tech products at the rate it once did, it is also incapable of generating workers in critical STEM fields such as computer science and electrical engineering, even though the best universities for these fields exist in the U.S (Atkinson & Mayo, 2010)
To combat this daunting issue, the Committee on a Conceptual Framework for New K-12 Science Standards began developing a new set of rigorous, all-encompassing science standards to ensure by the end of high school, every student will be able to:

- “Appreciate the beauty and wonder of science
- Possess sufficient knowledge of science and engineering to engage in public discussions on related issues
- Become careful consumers of scientific and technological information related to their everyday lives
- Continue to learn about science outside of school
- Have the necessary skills to enter careers of their choice including (but not limited to) careers in science, engineering and technology” (National Research Council, 2012, p. 1).

From these central aims, the NGSS were born. The NGSS are content science standards that set the anticipation of what students should be able to do by the end of a K-12 education. They are not curricula, but a set of performance expectations with the intent of addressing core concepts in the areas of Physical science, Earth and Space science, Life science, and Engineering and Technology (NGSS Lead States, 2013). Physical science, Earth and Space science and Life science are not new teaching topics in most school districts; however, many aspects of the NGSS are innovative.

One of the most ground-breaking features of the NGSS is the inclusion of three key dimensions: science and engineering practices, crosscutting concepts and disciplinary core ideas (Bybee, 2013). The weaving of these three dimensions throughout the NGSS is
to ensure students have multiple opportunities to actively participate in authentic science and engineering practices while applying concepts to add depth to their understanding of the core ideas in each field of science. Students will now apply the knowledge they have gained to real world problems and situations, similar to what scientists and engineers do on a daily basis, rather than memorize basic facts (National Research Council, 2012).

Another unique feature of the NGSS is the organization of the three dimensions into learning progressions. Previous science standards were not systematized causing gaps in learning or repetition of information. Incorporating learning progressions into the NGSS allows for the conceptual growth of science ideas and practices in a cohesive methodology throughout a K-12 education (Duncan & Ravit, 2013). One more difference between the NGSS standards and science standards of the past is the coverage of content. The learning progressions include fewer topics, focusing more on the depth of knowledge over the breadth (National Research Council, 2012).

In addition to all of the features of the NGSS listed above is the idea of who the target audience is for these new science standards. The answer to that question is everyone. During the creation of the NGSS, substantial effort was made to insure equity within the standards. In the past, science and engineering were fields reserved for the intellectually elite but as society becomes more advanced and complex, it is imperative that every citizen have the science skills and knowledge to not only encourage more people of all backgrounds into the fields of science and engineering, but also to be able to make decisions on issues that affect everyone (Pruitt, 2015).
Whether it is weighing the pros and cons of having a medical procedure or voting for a presidential candidate based on their stance on climate change, having a solid science base is critical. “Science is the true equalizer” in our society, but only when offered equally to everyone (Pruitt, 2015, p.3).

In 2015, in order to improve science scores and level the playing field in science classrooms, the state of Iowa’s Board of Education members adopted the new science standards for what students should know and be able to do upon completion of a standard kindergarten through 12th grade education (Iowa Department of Education, 2015). Upon this adoption, the Waterloo Community School District assembled a task force of science teachers throughout the district and across grade levels to begin the job of aligning science curricula to the new standards, with a goal of being fully immersed in the NGSS in all science courses by the 2018-2019 school year. The work of alignment began with familiarization with not only the three dimensions of the NGSS but also with the performance expectations of each science course.

Based upon those performance expectations, task force members decided to take this opportunity to change many aspects of the district’s science catalog. Currently within the Waterloo Community School District, students must complete three years of science in order to graduate. To maintain the graduation requirement, educators re-ordered courses, created new courses, redefined course descriptions and reviewed and piloted new textbooks and curricula.

The task force made many decisions regarding NGSS; however, every decision involved every science teacher within the district. All educators of the same grade level
or science topic worked together to assure horizontal alignment. Every science teacher at every grade level collaborated to insure vertical alignment, as well.

Once decisions became approved and finalized, the next task was to begin writing curricula, which is where my creative component project begins. I chose to do a creative component with the Next Generation Science Standards for a variety of reasons.

With an expectation of my curricula being fully aligned with the NGSS standards by the 2018-2019 school year, my goal was to write and present one complete unit encompassing at least one performance expectation (PE) to my students to better prepare myself for the complete transition to NGSS. In addition to preparing myself for this change in teaching, I was also curious in how this style of teaching and learning would affect not only student scores and overall grades but, mostly, I was interested in how this approach would affect their level of engagement and their understanding of the science concepts.

Lastly, I chose to do this creative component because even though I have only been teaching for 8 years, I am quickly becoming a leader in my science department and my school. I wanted to use this project as means of keeping myself on the cusp of science education so that I may facilitate others as we navigate through the integration of NGSS into our classrooms.

This creative component focuses on the HS-LS3 Heredity: Inheritance and Variation of Traits, specifically, the performance expectation (PE) HS-LS3-3 and uses the Science and Engineering Practices (SEP) of analyzing and interpreting data. It also
concentrates on the Disciplinary Core Idea (DCI) of variation of traits and it utilizes the Crosscutting Concept (CC) scale, proportion and quantity (NGSS Lead States, 2013).
Overview of the NGSS

In April of 2013, a new era in science education was unveiled through the NGSS. The writing of the NGSS began in 2011 and was a collaborative effort of 26 states and science education based organizations such as Achieve, the American Association for the Advancement of Science (AAAS), the National Research Council (NRC), and the National Science Teachers Association (NSTA). Over a two year period, this collective group developed the NGSS standards based on the National Academies of Science (NAS), *A Framework for K-12 Science Education*. The *Framework* outlines the comprehensive science and engineering topics and practices that all students should be familiar with throughout the course of a K-12 education career (NGSS, n.d.-f).

Common Core State Standards.

Mathematics and English Language Arts (ELA) have already created common standards under Common Core State Standards (CCSS) which is driving the push for science to develop and accept common standards as well (National Research Council, 2012). Additionally, CCSS share many commonalities with the NGSS in the desire to transform students into well informed, college and career ready members of society. For example, in the ELA, one standard requires students to “integrate multiple sources of information presented in diverse formats and media (e.g. visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and
accuracy of each source and noting any discrepancies among the data” (Center for Best Practices, 2010-a, p.1). Similarly, the mathematics standards places importance on reason and problem solving skills such as in the standard, “-the process of choosing and using appropriate mathematics and statistics to analyze empirical situations, to understand them better and improve decisions” (Center for Best Practices, 2010-b, p.1).

Another similarity between the CCSS and the NGSS is in the number of topics taught. The CCSS reduced the amount of math topics placing the emphasis on simply a few big ideas, or domains. For example, five domains outline the curriculum for Algebra: Introduction, Seeing Structure in Expressions, Arithmetic with Polynomials and Rational Expressions, Creating Equations, and Reasoning with Equations and Inequalities (Common Core State Standards Initiative, 2017). Equally, in biology, the NGSS focuses on only four key concepts: LS1: From Molecules to Organisms, LS2: Structure and Processes, Ecosystems, Interactions, Energy and Dynamics, LS3: Heredity, Inheritance and Variation of Traits, and LS4: Biological Evolution: Unity and Diversity (NGSS Lead States, 2013). Rather than go a mile wide and an inch deep, curriculum is going more in depth and focusing on fewer topics and consistency. At the high school I teach at, East High School in Waterloo, the common core has helped concentrate math teaching. According to the head of the mathematics department, Bonnie Nelson, “having fewer common core standards assists teachers in focusing their instruction rather than guessing at twenty broad topics. Common core standards also make it difficult for teachers to misinterpret what they are supposed to be teaching, leading teachers to take too many liberties within a curriculum,” (personal communication, May 4, 2018).
Countries with high-performing schools have been reducing the number of topics and seeing the results. Hong Kong fourth grade math students, for example, outscore fourth grade math students from the United States, even though the Hong Kong students cover only half of the topics (Daro, McCallum, & Zimba, 2010). Although the Hong Kong curriculum includes fewer topics, those topics are more centrally focused, coherent, and go into much greater depth (Daro, McCallum, & Zimba, 2010).

The need for NGSS is apparent and the time is right as well. The previous attempt to create common standards in science on a national level occurred over fifteen years ago. Since then, science, education and our understanding of how students learn has made great advancements (NGSS, n.d.-e). Science education needs to keep up with the times to continue to be relevant for the sake of society. But how is NGSS different from previous science standards?

**Why NGSS**

**Impact on Society**

The achievements of those in the science and engineering fields affect everyone, on every level. Whether it is the development of life saving medicines or the creation of systems that provide clean water, science and engineering infiltrate every aspect of our lives. Now more than ever, the need for more scientists and engineers is critical as the United States is slowly but surely struggling to compete in these fields with the rest of the world (National Research Council, 2012).

The call for more scientists and engineers is not only from these professional communities but also from such professions as politicians and economists as we count on
scientists and engineers to develop solutions to the world’s complex problems. The NGSS offer science standards that are more rigorous in nature and ask students to practice the skills performed by scientists and engineers. Not only will demonstrating how to think and act like scientists and engineers through the use of the NGSS encourage more people to seek careers in science and engineering fields, but it will also better prepare students for the challenges often found in higher education (NGSS Lead States, 2013).

The NGSS demand students think critically and become problem solvers which are not only skills required to succeed in college but likewise prepare them for the world of work. It will also create a more scientifically informed society who is better able to make knowledgeable decisions on personal, local and global levels (National Research Council, 2012).

**Student Equity**

In order to better create a scientifically literate society, all of its members must have an “equitable learning opportunity” (NGSS, n.d.-b, p.1). Every student is able to interact and be successful within a science classroom, no matter their backgrounds, when provided with an equal education (NGSS, n.d.-b).

Unique to the NGSS is the emphasis on making science accessible to all students regardless of race, gender or ability. The demographics of the traditional classroom are changing and diversity is on the rise. Yet even though student diversity is increasing in the classroom, achievement gaps continue to divide students (Lee, 2015). Since its inception, NGSS has touted the phrase, “all standards, all students” to highlight the need
to include those that have been habitually underserved (Lee, 2015, p. xi). Examples of students considered underserved are students who are economically disadvantaged, from major racial and ethnic groups, disabled, limited in English proficiency, in alternative education programs, females, and gifted and talented (NGSS, n.d.-b).

The NGSS strives to close achievement gaps through a variety of methods. First and foremost, the standards themselves are more rigorous than previous science standards and will require all students to increase their cognitive abilities. Additionally, including an engineering aspect to the science standards allows for creative and inventive hands-on opportunities for students create meaning and develop science relevancy in the lives of those historically relegated in science classroom (NGSS, n.d.-b).

The Three Dimensions of NGSS

NGSS stands out from other science standard reform movements in many different ways. First and foremost, the NGSS presents in a three dimensional (3D) approach, the three dimensions being Science and Engineering Practices (SEP), Crosscutting Concepts (CC) and Disciplinary Core Ideas (DCI) (Bybee, 2013).

Science and Engineering Practices

One of the first and foremost changes science teachers will notice that sets the NGSS apart from other science standards is the inclusion of the SEPs. The addition of the terms “engineering” and “practices” to the science standards is highly indicative of the direction and intent of the NGSS on student learning (National Research Council, 2012, p. 42).
The term engineering is purposely used to describe the types of activities students are to engage in through the NGSS (Bybee, 2013). Science and engineering are complimentary to each other in many ways. While science provides questions and answers about the natural world, engineering recognizes problems and proposes solutions (Bybee, 2013). Science and engineering work together to allow students opportunities for deeper understanding by challenging students to apply the knowledge of science to a real world problem and design a possible solution (Bybee, 2013).

Furthermore, the union of science and engineering applies again as students test their designs and continue to tweak them until they work (Pruitt, 2014). Adding the term engineering also indicates the inclusion of more technology into science curricula (Bybee, 2016).

The word practice is also intentionally used for a variety of reasons. First, the term practices emphasizes that science is not a passive endeavor, but rather a process, a process that does not have a specific, step-by-step recipe to follow (National Research Council, 2012). By incorporating the term practices calls students to engage in the nature of science and indicates that science requires a collaboration of knowledge and skills, not just one or the other (Duncan & Caver, 2015).

Finally, and most importantly, practices refer to the way science and scientists work in the real world and how new knowledge comes about. The NGSS asks students to approach science as an actual scientist would rather than learn science through the memorization of facts and vocabulary (Duncan & Caver, 2015). The following is a list of the NGSS science and engineering practices:
1. “Asking Questions and Defining Problems
2. Developing and Using Models
3. Planning and Carrying Out Investigations
4. Analyzing and Interpreting Data
5. Using Mathematics and Computation Thinking
6. Constructing Explanations and Designing Solutions
7. Engaging in Argument from Evidence

Not only do these practices incorporate the core of both science and engineering, they promote a more active, student-centered classroom.

Disciplinary Core Ideas

The Disciplinary Core Ideas, or the DCI’s, are the need to know, essential concepts students must master before they graduate from high school. For each of the major disciplines, life science, physical science, Earth and space science and engineering, there are no more than four DCI’s per discipline (Duncan & Cavera, 2015). The idea of having a few DCI’s per discipline is another difference in the NGSS from previous science standards. Rather than present a large body of scientific facts for students to memorize, the NGSS embraces the fact that we live in an age of information where students can access answers to questions at the touch of a button (Duncan & Cavera, 2015). Knowing this, the NGSS instead focuses more on a few core concepts and delves deeper into those concepts. This emphasis on depth over breadth should still provide
students with the necessary knowledge needed to make informed decisions but also enable them to think critically and evaluate scientific information and reliable sources so that meaningful learning can continue well beyond the formative years (NGSS Lead States, 2013).

**Crosscutting Concepts**

The final dimension of the NGSS is the Crosscutting Concepts. The crosscutting concepts or the CC’s, are the basic science themes that span all science disciplines throughout all grade levels. Identification of these themes not only wholly unifies the science disciplines and demonstrates commonality, but they also help students to make connections to the real world (NGSS Lead States, 2013). Additionally, students trained to recognize these overarching concepts will be better able to apply those themes and make predictions when faced with new science information. The following is a list of the crosscutting concepts for K-12 science education (Bybee, 2016):

1. “Patterns
2. Cause and effect: Mechanism and explanation.
3. Scale, proportion, and quantity
4. Systems and system models
5. Energy and matter: Flows, cycles, and conservation
6. Structure and function
7. Stability and change” (NGSS Lead States, 2013, p. 91).

While many states standards recognize these dimensions throughout their assessments and instruction, it is often not collaboratively as in the NGSS, but rather as
separate entities (NGSS Lead States, 2013). This separate treatment of the dimensions has become evident in recent years as assessment has become the front runner, driving many teachers’ curriculum and instruction (Bybee, 2013). In order to avoid this separate treatment of the dimensions, the creators of the NGSS developed Performance Expectations (PEs). The PEs are learning outcomes designed to reflect all three of the NGSS dimensions and, if incorporated into the classroom correctly, will increase the level of rigor and relevance within a science curriculum (NGSS Lead States, 2013).

Below is an example of PE HS-LS2-1:

“Use mathematical and /or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales” (NGSS Lead States, 2013, p. 270).

Elements of all three dimensions are evident in this (and all) performance expectations (Bybee, 2013). For example, the use of math or computation to support explanations demonstrates science and engineering practices. The topic of carrying capacities and the factors that affect them within an ecosystem exemplifies a disciplinary core idea. Finally, challenging students to explain how those factors affect carrying capacity of organisms at different scales best represents the crosscutting concept of scale, proportion and quantity (NGSS Lead States, 2013). Not only does the PEs intertwine the three dimensions but they translate in way that does not describe specific activities but rather provides guidance for the teacher and allows for the teacher to choose how that PE can be best accomplished in their classroom (Krajcik, Codere, Dahsah, Bayer, & Mun, 2014).
The PE is also an active statement, requiring students to demonstrate what they know rather than the memorization of facts. This also sets the stage for assessment and will assist in the writing of lesson plans in the Understanding by Design format (Bybee, 2013).

**Understanding by Design**

Understanding by Design, (UbD) is a system of course development for improving student achievement that allows the teacher to be the designer of student learning (Authentic Education, 2015). UbD is ideal for a curriculum driven by the standards as it assists teachers in identifying clear learning goals, creating useful assessments and planning meaningful learning opportunities all through the use of a backwards design (Authentic Education, 2015).

Traditionally when it comes to lesson planning, teachers rely on the information and order of the textbook and the conventional labs and lessons plans that have held students attention for many years to plan their lessons. Although students maybe engaged in these lessons and labs, the question is whether understanding is taking place. To make learning more purposeful, UbD prescribes a backwards design of lessons outlined in three stages:

- “Stage one: identifying the desired results
- Stage two: determine the acceptable evidence
- Stage three: plan learning experiences and instruction” (Wiggins & McTighe, 2011, p.18).
The first step in the UbD process asks educators to begin lesson development by first deciding what students should know, understand, and be able to do by the end of the unit (Wiggins & McTighe, 2005). By identifying the desired results first, educators can prioritize information and focus on activities that will allow students to achieve deeper learning and essentially, maximize student understanding by the design of the lesson. Using the UbD process will not only increase the likelihood of student understanding, but its three step process aligns well with the scheme of the NGSS. For example, the NGSS performance expectations are an ideal starting point for the stage one portion of UbD of identifying the desired results (Bybee, 2013).

The second step in the UbD process is to develop assessments that will accurately reflect whether students have achieved the results anticipated in the first step (Wiggins & McTighe, 2005). Often this step is the toughest for teachers as it asks them to “think like an assessor” instead of a planner of lessons, assignments and activities, which is what would come normally after identifying the big idea for the traditional teacher (Wiggins & McTighe, 2011, p.18).

The advantage to creating the assessments before developing the lesson plans is that educators will think more specifically about the desired outcomes they want their students to achieve and exactly how students are going to demonstrate their understanding of that big idea. Another advantage to creating assessments before the lesson plans is that it gives educators an opportunity to think critically about the types of assessments that will best reflect what teachers want their students to know (Wiggins & McTighe, 2011). By designing the unit using UbD, the lessons will be more clear and
articulate and students will understand the big idea because teachers have intentionally
designed their assessments and lessons around those big ideas rather than leaving the
responsibility of understanding solely on students shoulders (Wiggins & McTighe, 2011).

The third step in the UbD process is to plan the learning experience and
instruction (Bybee, 2013). With the outcomes clearly acknowledged and the assessments
developed, now is the time to begin collecting the activities, lesson plans, resources and
materials that will best support those goals. This is also the time to think about whom the
students are and what they will need to be successful (Wiggins & McTighe, 2005).

Assessments and NGSS

Adding to the challenge of developing lesson plans in the UbD three step process
is the idea of how educators assess in the three dimensions of the NGSS. Conventionally,
teachers rely on the cumulative, end of the year paper and pencil tests and quizzes that
include such components as multiple choice questions, matching, and fill in the blank.
Generally, these types of assessments only test the DCI piece of the NGSS. Although
these types of tests are easier to grade, they unfortunately will not support the many of
aspects of the PE’s of the NGSS (National Research Council, 2014).

To sufficiently assess PEs, tests now need to be multi-faceted and focus on
scientific practices specific to the disciplinary core ideas while making connections to the
cross-cutting concepts (National Research Council, 2014). Not only will tests need to be
multi-faceted, they also need to take place at the beginning and throughout a chapter or
unit to allow educators to collect evidence of student learning to better direct their
instruction (Hockett & Doubet, 2013).
Pre-assessment

Whether gathered from school, home or the media, every student comes to the classroom with preconceptions about most science topics. Preconceptions are “inventions of the mind of each individual in response to personal experience” (Schmidt, Woodworth-Saigo, & Stephans, 2006, p.27). While some of their preconceptions may be accurate, some may be erroneous. Teachers frequently make assumptions about what students know or ought to know by the time they reach their classroom, and begin their teaching at where they believe students have left off without truly measuring what students actually know. In order to effectively close learning gaps and uncover prior knowledge, a pre-assessment given at the beginning of a unit serves to inform teachers of student understanding (Keeley, 2008).

A pre-assessment is a way to gather evidence of students’ experiences and background knowledge before the lesson or unit to inform and drive instruction (Hockett & Doubet, 2013). Administering pre-assessments prior to teaching serves multiple purposes. In addition to prompting initial student ideas, pre-assessments can bring to light persistent misconceptions students often transfer with them from grade to grade (Keeley, 2008). Identifying misconceptions can also assist teachers in recognizing how those misconceptions were initially formed and then permanently correct the error (Keeley, 2009).

Pre-assessments effectively and efficiently inform teachers of what students know and do not know, allowing teachers to differentiate instruction to meet the needs of every learner (Keeley, 2009). Not only is pre-assessing beneficial to the teacher, it is also
valuable to the student as once they realize their shortcomings they are more focused and motivated to learn what they do not know (Conderman & Hedin, 2012). Additionally, pre-assessing students previous to a lesson or unit permits a teacher to prioritize instruction and essentially, save class time (Hockett & Doubet, 2013).

Formative Assessment

Equally as important as pre-assessments are the informal methods used daily to provide evidence of student learning during a unit or lesson plan in order to make instructional adjustments, collectively known as formative assessments (Tomlinson, 2014). Examples of formative assessments could be as simple as teacher observations, teacher-student conversations, white boarding activities, student signaling, journals, exit and entrance tickets, and short homework assignments (Conderman & Hedin, 2012). Not only are these types of assessments frequently administered, but they are also generally not graded (Tomlinson, 2014).

Formative assessments serve a range of purposes for both teachers and students. Teachers benefit from formatively assessing students throughout a unit as not only does it give teachers a glimpse as to how students are progressing in their learning, but it also allows teachers to analyze errors in student thinking (Keeley, 2008). As these errors in student thinking surface, teachers can purposefully reflect on their instruction and make plans on how to reteach the follow day. Essentially, formative assessment allows teachers to form a “bridge between today and tomorrow’s lesson” (Tomlinson, 2014, p.14).

This type of reflective teaching allows teachers to group students together with similar abilities and skills, and sets the stage for differentiated instruction in the
classroom. Teachers can also glean information such as student learning preferences and interests from these simple types of assessments to further drive their instruction (Conderman & Hedin, 2012).

Students also reap the benefits of formative assessments. Regular formative assessment affords students the opportunity to examine their own work and get constructive feedback from the teacher without it affecting their grade (Tomlinson, 2014). Administering these types of assessments on a consistent basis keeps them informed of where they are in their learning and where they need to be. Formative assessments allow students to make adjustments to their thinking and ultimately to take charge of their own learning. It also provides students an opportunity to demonstrate their knowledge and show the improvements they have made in their education (Conderman & Hedin, 2012). Formative assessments exhibit to students the nature of learning and that “assessments help them learn and that immediate perfection should not be their goal” (Tomlinson, 2014, p. 15).

**Summative Assessment**

Similar to formative assessments, summative assessments are assessments that periodically test what students know and do not know (Garrison & Ehrlinghaus, 2013). However, summative assessments differ from formative assessments in many ways. Summative assessments occur less often, generally occurring at the end of a chapter, unit, or semester (e.g. exams, comprehensive projects and state or district assessments) (Conderman & Hedin, 2012). These types of assessments are high stakes and are often included in the students class grade (Garrison & Ehrlinghaus, 2013).
Because summative assessments come at the end of a chapter or unit, the information gained from them is not used to assist the students or teachers in the learning process but rather used to make the decisions that affect concerns outside of the classroom. For example, summative assessment results assist in not only assigning grades but also in promoting or retaining students or grouping students by styles of learning (National Research Council, 2014).

Summative assessment is, perhaps, one of the most challenging aspects of the NGSS. As summative assessments have a “disproportionately large impact on curriculum, instruction and outcomes”, creating high-quality assessments that accurately and effectively assess student learning will be critical to the overall success of the NGSS (Flanagan, 2013, p.1). Adding to that challenge is developing assessments that not only assess science proficiency but do so in a manner that is feasible for the students and the teacher (Pellegrino, 2013). Examples of testable NGSS tasks would include developing and refining models, generating and analyzing data, constructing spoken and written scientific explanations, engaging in evidence-based argumentation, and reflecting on their own understanding (National Science Teachers Association, 2014).

Below is a sample list of possible assessment tasks for the topic of colony collapse disorder:

A. “Use provided data on honey bee populations to graph the change in U.S. bee colony numbers over time on a scatterplot.

B. Reconsider the scatterplot of U.S. bee colony numbers. Make a prediction on how bee colony numbers will change in the future.
C. Construct an argument of how continued trends related to changes in bee colony numbers might be impacting the stability and biodiversity of ecosystems and agricultural systems in which bees participate.

D. Based on external research, construct a list of suggested solutions for colony collapse disorder” (NGSS, n.d. –c, p.5-7).

The nature of these assessment investigations clearly steers away from memorization of content and instead requires students to demonstrate knowledge and skills similar to how science and engineering is practiced in the real world (National Research Council, 2014).

Learning Progressions

Functioning to support educators in instruction and assessment development is the idea of learning progressions. Learning progressions in science are “empirically grounded and testable hypotheses about how students’ understanding of, and ability to use, core scientific concepts and explanations and related scientific practices grow and become more sophisticated over time, with appropriate instruction” (Corcoran, Mosher, & Rogat, 2009, p.8). Included in the design of the NGSS is a system of learning progressions to promote coherence in conceptual growth in scientific processes throughout a student’s K-12 education (Duncan & Rivet, 2013).

Learning progressions are not synonymous with scope and sequences. Rather, learning progressions are heavily researched stages of how students actually come to understand core science ideas. Learning progressions also emphasize depth of knowledge and “developing increased complexity and applicability” (Duncan & Rivet, 2013, p.1).
Recent research suggests a positive correlation between learning progressions and assessment as more educational leaders are calling for the development of those learning progressions to support teachers in the classroom. In an attempt to integrate learning progressions, educators are utilizing student work in order to initially create learning progressions while using assessment tools to further enhance those learning progressions (Furtak, Morrison, & Kroog, 2014).

To provide teachers with information, student knowledge, and skill level, assessments of all kinds connect to different levels of growth along the learning progression (See Figure 1). Not only does this assist teachers in responding to student thinking but it also benefits teachers in inferring student results (Furtak, Morrison, & Kroog, 2014).

Figure 1: Sample Learning Progression (NGSS, n.d.-a)

Pedagogy and Methodology of the NGSS

Constructivism can be summarized by stating that knowledge is built, or constructed, through real-life experiences. Constructivism is naturally problem-based learning that allows for new information combined with existing information in order to adapt knowledge and make sense of experiences (Chmiel, 2014). In practice,
constructivism would require students to create their own understanding through learning that involves experimentation and problem solving activities that call upon previously learned information in order to integrate new information. This information is then applied to new, perplexing situations that require students to review and revise their current understandings (Ormrod, 2006).

The theory of constructivism consists of two branches: cognitive and social. Developed by the Swiss biologist, Jean Piaget, cognitive constructivism states that learning is personal and requires great individual thought in order for learners to fully understand a concept, as opposed to just being able to recite the information (Ormrod, 2006; Powell & Kalina, 2009). Central to this theory are the experiences and background knowledge students bring to the classroom and how students add to that knowledge over time. Piaget referred to this process as assimilation and accommodation (Ormond, 2006).

Assimilation occurs when students acquire new information and relate it to what they already know, or what Piaget referred to as a “scheme”. A scheme is an organized group of similar actions or thoughts (Ormond, 2006, p. 25). If students are unable to assimilate the information, meaning they have no scheme or experience that is consistent with the new information, accommodation may then transpire. Accommodation simply put, is the changing or replacing of old ideas based on new information (Ormond, 2006).

The NGSS incorporates the theory of assimilation and accommodations through the use of learning progressions throughout a K-12 educational career. An example of assimilation and accommodation in Biology is evident in the topic of heredity. Through the NGSS, students in elementary school identify traits in similar organisms and discuss
the topic of inheritance of those traits from parents. They also discuss how the environment can influence the expression of those traits. In middle school, students add to that knowledge by studying how those traits manifest from the DNA into proteins. Also at the middle school level, students will learn how mutations in the DNA can lead to changes in the shape of proteins resulting in beneficial, harmful or benign changes in the structure and function of an organism. As students’ progress into high school, they will optimistically assimilate how the information in the DNA passes from parent to offspring through the process of meiosis and they will hopefully accommodate how the replication of DNA and environment factors play a role in the creation of possible mutations (NGSS Lead States, 2013).

Social constructivism is learning that occurs as a result of the social interactions and student experiences within a classroom (Powell & Kalina, 2009). Established by Russian psychologist Lev Vygotsky, social constructivism contrasts Piaget’s cognitive theory in that it places more emphasis on the role of adults, society and culture in student learning (Gallagher, 1999; Ormond 2006). Vygotsky believed the role of an adult in the learning of a student was critical, as adults could provide guidance and scaffolding to give a new experience or discovery more meaning.

Interaction with peers is also a large facet of social constructivism. Vygotsky believed that students had two levels of abilities. Those abilities students perform alone, also known as a student’s actual developmental level and those abilities students perform in a group of more advanced or skilled students or with a teacher, known as a student’s potential development level (Ormond, 2006). At the potential development level, the
theory states that students are more capable of having success when collaborating with adults or higher achieving peers (Ormond, 2006). Vygotsky’s theory of social constructivism would include classroom activities where students work in groups such as lab activities, research projects and debates.

An example of Vygotsky’s theory in the NGSS biology classroom could be a group debate over the advantages and disadvantages of the mapping of the human genome. Debating this topic would demonstrate to students the multiple opinions and viewpoints, such as knowing whether one is a carrier for a specific genetic disease versus possible genetic discrimination. Asking students to debate the pros and cons of a topic such as the Human Genome Project is a prime example of the critical science and engineering practice of engaging in argument from evidence.

**The Importance of Teaching Heredity**

Due to the intricacy and abstract nature of the topic, heredity and genetics is often one of the most difficult portions of a biology curriculum to teach (Galea, 2016). With the bombardment of genetics in the news and in popular television shows, many students come to class with their own prior knowledge and misconceptions, and even with exposure to experienced teaching, many students hang on to those misunderstandings throughout the rest of their lives.

Most students understand that offspring resemble their parents; however, how those traits are inherited is where the confusion begins. In surveys compiled by Driver, Squires, Rushworth, and Wood-Robinson (1994) a majority of students are familiar with the term “gene” but less familiar with the term “chromosome”. Even less familiar are
students with understanding of the role of those units in inheritance and variation in offspring. For example, many students believe that traits from parents are blended together in the offspring. Still other students believe that traits are gender specific, meaning, the mother’s traits are stronger in female offspring while the father’s traits are stronger in male offspring (Driver, Squires, Rushworth, & Wood-Robinson, 1994).

Student ideas on variation were also vague in that most students concluded that variation within a population was due to environmental factors instead of due to sexual reproduction. Additionally, students could calculate the probability of certain traits occurring with theoretical examples but when it came to applying it to real-life family situations, students could not make that connection (Driver, Squires, Rushworth, & Wood-Robinson, 1994).

Now, more than ever, it is important for high school students to understand the concept of heredity as our genetic information is being utilized to answer questions about our health and to solve reproductive issues (Mills-Shaw, Van Horne, Zhang & Boughman, 2008). Yet even though students of this generation are more exposed to the science of genetics, many are unable to understand the subject on a level necessary to apply it to their everyday lives (Lewis & Wood-Robinson, 2000).

At the college level, genetics courses are becoming required courses rather than just for those “intellectually ambitious” students (Redfield, 2012, p.4). At the high school and middle school level, 80% of the science standards adopted since 2003 include vocabulary such as, Human Genome Project, bioethics, cloning, and stem cells (Mills-Shaw, Van Horne, Zhang & Boughman, 2000). Not only is the importance of
understanding genetics reflected in education, but, genomic based products are rapidly becoming common household names as well.

With the completion of the Human Genome Project, the widespread effort to map and sequence the entire human genome, humans are quickly becoming the best understood genetic system (McGowan, 2005; Redfield, 2012). As a result, the popularity of home genetics testing kits from companies such as Ancestry.com and 23andme is on the rise. Students need to be informed consumers able to make informed decisions regarding knowing or not knowing their DNA (Redfield, 2012).

Societal issues are also a factor when it comes to the topic of genetics and the importance of including it in a high school biology curriculum. Science educators are often thought of as a link between the world of science and its application to the real world. It is imperative to present to students not only genetics core content but also new technologies in the field of genetics and moral, ethical, and legal implications of these technologies on society (Lazarowitz & Bloch, 2005).
CHAPTER 3

METHODS

Curriculum Development

The unit I planned for the creative component portion of this research paper focused on the PE HS-LS3 Heredity: Inheritance and Variation of Traits, specifically, the PE HS-LS3-3: Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population. This PE includes the SEP of analyzing and interpreting data and concentrates on the DCI of variation of traits. This PE also incorporates the CC of scale, proportion, and quantity (NGSS Lead States, 2013).

To plan the unit, I used the UbD (see Appendix A) method of backward lesson design. The first step of UbD was identifying the desired results. In order to thoroughly ascertain what I wanted my students to know and be able to do by the end of the unit, I utilized the processes of unpacking the standard, creating a know, understand and be able to do chart (KUD), writing essential questions and performing a curriculum topic study (CTS).

Unpacking the Standard

The purpose of unpacking the standard was to properly identify what students should know and be able to do by the end of the unit, according to that standard. In order to unpack a standard, the verbs were picked out and labeled as the skills students must be able to perform, while the nouns were identified as the content students should understand by the end of the lesson.
Once the standard was unpacked and the skills and concepts were determined, the KUD’s were written. The KUD’s are what students should know, understand, and be able to do by the end of the unit (see Appendix B).

**Essential Questions**

After the KUD’s were written, I wrote two essential questions to focus my unit. The essential questions are the key ideas and goals of the unit and aid in prioritizing learning. The questions formulated are broad, overarching questions that students cannot answer with one word or by looking it up on the internet. Rather, students will need extensive background knowledge and data to provide a fully developed answer (Wiggins & McTighe, 2011).

The following two questions were developed to demonstrate what students should know and be able to do at the end of the unit:

- Describe how two parents can have multiple children together, yet each of their offspring is unique and displays different traits in their phenotype?

- Explain, using patterns and mathematics, how one can predict the probability of a specific trait or characteristic appearing in the phenotype of an offspring?

**Curriculum Topic Study**

When the KUD chart was complete and the essential questions were written, I began research on the curriculum topic study (see Appendix C). The curriculum topic study, or CTS, is a “systematic professional development strategy that links science standards and research to curriculum, instruction, and assessment” (Keeley, 2005).
variety of resources such as Science for All Americans, American Association for the Advancement of Science, Science Matters, and Benchmarks were utilized to fully research the ideas and understandings behind the selected PE.

Assessments

The second step in the UbD style unit of planning is to determine the acceptable evidence of student learning. This means not only planning the assessments that will best demonstrate whether students have achieved the learning goals for the unit, but also creating the rubrics that will assist me in analyzing student work. I began by creating a pre-assessment (see Appendix D) to gauge what students already know or what misconceptions students may have developed from previous science classes or experiences. I then planned formative assessments (see Appendices E & F) to be performed throughout the unit. These formative assessments came in the form of entrance questions, assignments, and exit questions to insure students are meeting the targeted learning goals.

Next, activities and accompanying sheets were created (see Appendix G) to allow students to practice skills, such as Punnett squares and pedigrees. Finally, I created an authentic summative assessment (see Appendix H) that asks students to demonstrate their knowledge on the learning goals. I also created a rubric to accompany the summative task in order to fairly evaluate student success. In addition to the authentic summative task, students also took a traditional summative test (see Appendix H) that includes questions that will not only gauge their knowledge and understanding of the learning goals but also
questions to measure their depth of knowledge on the overarching essential questions created in step one of the UbD procedure.

**Lesson Plans**

The last step in the UbD process is to plan the suitable learning activities that will allow students to reach understanding (Wiggins & McTighe, 2011). The unit began with a phenomenon and the lesson plans that followed were created using the 5E learning cycle (see Appendix I) of engagement, exploration, explanation, elaboration, and evaluation (Biological Sciences Curriculum Study, 2011). Activities were hands on and interactive in nature and centered on a driving question. Real world topics and purposeful genetic issues that affect and interest students were built-in and dispersed throughout the unit. Supplementary activities were created for both struggling students and for those students in need of more challenging work (see Appendix J). Students also had multiple opportunities to work collaboratively with other students as well as time to reflect and work on their own.

**Assessing the Curriculum**

Upon completion of the unit, I worked with my collaborator to assess my lessons using the Educators Evaluating Quality of Instructional Products (EQuIP) rubric (see Appendix K). The EQuIP rubric is a tool to evaluate the quality of lessons in three different categories: NGSS Three Dimensional Design, NGSS Instructional Supports, and Monitoring NGSS Student Progress (NGSS, n.d.-d). In the first category, lessons are evaluated based on criteria such as the inclusion of phenomena, science and engineering practices, disciplinary core ideas and crosscutting concepts. This category also measures
for connections to math and English state standards as well as connections to other science disciplines (NGSS, n.d.-d).

The second category examines for student engagement and equity. Examples of the criteria looked at in this section would be relevance to students, authentic science scenarios, opportunities for students to express ideas, consideration for prior knowledge, and differentiated instruction (NGSS, n.d.-d). The last category evaluates lessons for the amount and types of assessments utilized throughout the unit. Examples of criteria evaluated in this category would be the presence of pre-, formative and summative assessment that sufficiently measures three dimensional learning, the inclusion of scoring guides, such as rubrics, and opportunities for students to receive feedback from peers and teachers (NGSS, n.d.-d).

Each criterion in every category is first measured by the amount and quality of evidence presented in the unit and is then rated as Extensive, Adequate, Inadequate or None (NGSS, n.d.-d). Once each criterion is rated, a score is given separately to each category on a 0-3 rating system. In order to receive a three, all criteria must receive an adequate rating and some must receive an extensive rating.

Once all the categories have been rated, the ratings are totaled. High quality NGSS units receive a total score of 8-9. Units that are considered high quality, but need some improvement would receive a score of 6-7. Any unit receiving a score of 5 or less would need significant revision (NGSS, n.d.-d).
CHAPTER 4

REFLECTION OF THE PROJECT

Results of the Equip Rubric

Upon completion of the unit, my collaborator and I worked together to assess the unit using the EQUIP rubric (see Appendix K). Through many discussions and deliberations, my collaborator and I came to a consensus and awarded the unit an overall score of 7 which translates into an “adequate” unit that could use some improvements in one or more of the categories.

Category I over the NGSS 3D design of the unit received the highest marks with a rating of 3 as each sub-category had adequate to extensive evidence of SEP’s, CC’s and DCI’s. SEP’s that were covered during the unit were Asking Questions and Defining Problems, Developing and Using Models, Analyzing and Interpreting Data, and Using Mathematics and Computational Thinking. Crosscutting Concepts that were addressed in the unit were Patterns and Cause and Effect, while Inheritance of Traits and Variation of Traits were the DCI’s that were covered throughout the unit. Besides having multiple areas of 3D learning, the extensive incorporation of math strengthened the unit as well.

Category II involved the NGSS instructional supports provided through the unit to insure engagement of all students. Although most of the sub-categories in this section received adequate to extensive scores, one sub-category received an inadequate rating which dropped the overall rating to a 2. Not having my activities translated into other languages for ELL students was one reason my lesson scored lower. However, I do not have ELL students and if I had, I would have had the lessons translated. I also did not feel
like I gave students enough opportunities to express or clarify their ideas and to respond to other students’ ideas throughout the lesson. For this reason, this sub-category received an inadequate rating. Assets of this category were that the unit was relevant and authentic and gave students first-hand experience at doing science. The unit was also scientifically accurate and provided students at all learning levels differentiated and appropriate instruction.

Category III evaluates the monitoring of student progress of the NGSS unit. Again, most sub-categories were given an adequate or extensive rating with the exception of scoring guidance which received an inadequate rating. The reason for the low rating is that on the activities, worksheets, labs and projects, only one worksheet, the Pedigree Project, had a rubric with it to inform students of how they would be graded. In order to improve this category, I should have added point values and rubrics to the activities so that students would have a better understanding of how to best complete the assignment.

Positives in this category were that monitoring of student progress was a constant procedure and took place on a daily basis with a variety of formative assessments in the form of a pre and post assessment, entrance and exit slips, practice activities and multiple choice common formative assessments that helped drive my instruction.

Overall I think the unit was well designed and had high quality activities that were engaging for all students while giving them an opportunity to do authentic science tasks. I also felt that the unit covered all aspects of the NGSS exceedingly well and offered many learning opportunities for students of all abilities. What would have helped improve my score on the rubric is if I had written my lesson plans not just for myself but with another
teacher in mind. There were many things I did on a daily basis, such as whiteboarding activities, that I did not include in my lesson plans as often times these were done on a moment’s notice. I also felt that in order to improve my score on the EQuIP rubric, I should have included a script of what to say for each day of the unit.

Using the EQuIP rubric to evaluate my lesson was an informative and useful experience that I could see doing again for future lessons and units as we build our curriculum to align with NGSS. I especially enjoyed working with my collaborator to get his perspective on the unit as he offered new insight into both the positives and the negatives of the unit.

Reflection of the Implementation of the Unit

As I reflect on the implementation of this unit, there were some very encouraging outcomes I witnessed as we progressed through the lessons. Beginning the unit with a pre-assessment and phenomena was very beneficial and a must add to all my future units. The pre-assessment and phenomena not only demonstrated to me the information students had and what they were lacking but it was also engaging for the students and really got them to question their science knowledge. The “Observing Human Traits” lab (see Appendix G) was also a success. Students loved tasting the different chemical papers to see who was a taster and who was a non-taster. They did a great job of collecting data of other human traits and using that data to create graphs and analyze the results. The activity that had the most impact on the students and their global outlook was the “Determining Sex in Sea Turtles” lab (see Appendix G). Many of the students were amazed that the sex of reptiles was determined by temperature but then when the topic of
climate change came into play, many students realized the long term effects that global warming could have on not just our population but the population of other organisms as well. It was refreshing to see students care about an issue that is not directly related to them.

Finally, one of the biggest surprises for me in this unit was the math portion. I had planned to spend a lot of time discussing and practicing probability problems (see Appendix H) before jumping into Punnett squares but there was no need as my students’ demonstrated proficiency within one lesson.

**Improvements of the Unit**

Although I personally felt that my unit was an overall success, my pre and post assessment scores do not support those feelings. The pretest shows a picture of Lucy and Maria Alymer who are fraternal twins (See Figure 2). Their father is white and their mother is half Jamaican.

*Figure 2:* Fraternal twins Lucy and Maria Alymer. This photo demonstrates that even though children inherit the same genes from their parents, expression of those genes is what makes everyone unique. Adapted from Mirror, 2015.

Students were then asked to choose which of the following statements best
explains how this phenomena occurred?

a. Children inherit more traits from the father than from their mother

b. Children inherit half of their traits from the father and half from their mother

c. Male traits are stronger than female traits

d. The daughter with white features inherited more traits from her dad than the daughter with mixed race features

e. Parent’s traits don’t matter, the environment determines the person’s traits

f. A person’s traits are dependent on their blood type

The results from the pre-assessment reveals that more students chose answer D over the correct answer of B with a small number of students choosing option A or F. Upon taking the post-assessment, there was an increase in the number of students who chose the correct answer of B and the number of students that chose D did decrease, however, more students still disappointingly chose the incorrect answer of D over the correct answer of B. This, unfortunately, completely supports Driver, Squires, Rushworth and Wood-Robinson’s concepts on genetics misconceptions in that students could calculate the probability of certain traits occurring with theoretical examples but failed to accurately apply that information when presented with real-life examples (1994). The amount of students who still chose the incorrect answer also demonstrates how persistent misconceptions can be and also how vital it is to student learning to correct those misconceptions (Keeley, 2008).

Reflecting on this data, one solution I had to improving the post assessment score was that I should have referenced the pre-assessment question and the accompanying
picture throughout the unit more than I did. As I contemplate changes in my unit, I would incorporate that picture and perhaps depicting similar genetic situations after activities such as the “Observing Human Traits” lab, the “Mendelian Coin” lab and the “Punnett Square Practice” worksheet (see Appendix G). Referencing this picture and asking students to relate what they learned to how these twins came to look so different from one another would have not only helped students better understand the concept of genetics but also, I believe, would have dramatically increased their post-assessment score.

Furthermore, I believe a factor in the low scores was the terminology I used in the pre- and post-assessment. Answer D, the most chosen answer, stated that one daughter inherited more traits from her dad than the other daughter. I believe if I had used the term “genes” instead of “traits” less students would have chosen D as their answer. I feel that most students truly understood that each parent gives the same amount of genes but the fact that one daughter clearly expresses more of her father’s traits may have caused confusion for the students and led them to choose answer D over B. Perhaps adding a short writing portion to the pre-/post assessment would allow students to explain their answer choice and provide more insight into their depth of understanding.

Another aspect that may have accounted for the low scores for the post assessment stems from apathetic students. This unit came at the end of the year as many students get weary of the day to day challenge of school. I strongly feel that a large portion of students simply put a letter down with no thought in their choice but instead to just get it done as I did not make this a graded assignment. Perhaps changing the post
assessment to make it a graded assignment or part of a test would encourage students to put forth more effort.

An additional change I would make to this project is to the “Observing Human Traits” lab (see Appendix G). As an additional assignment, I would like to have my students visit other classrooms in the school and collect data on the various traits included in the lab. I believe this would make the data collection process more meaningful and interesting and it would also serve to demonstrate how having a larger sample size increases the mathematical accuracy.

One more change I would make to this unit is the culminating Pedigree Project. This was a worthy activity and was fitting for the final project; however, I do not feel it was a good fit for my students. As students were working on it, I overheard many of them say they did not know their families or they were adopted and because of this, many students eventually decided to just make up a pedigree of a pretend family. I understand this and anticipated this reaction from some students so the lesson was created with this in mind and there were alternatives. However, none of the students chose the alternatives presented and instead created a pretend family in order to complete the project. This made me wonder if doing this project made students feel unhappy as it is a reminder that they do not know or have blood relatives in their lives. Additionally, many students who know their family still used a pretend family as they were too indolent to actually do the little bit of research required to complete the pedigree.

For these reasons, students will no longer create a pedigree of their family but rather the main project will be instead having students create a pedigree of a fictional
organism. I also plan on making the rubric more rigorous so that students feel compelled
to give their best effort. Finally, I will implement a writing portion to the project so that
students have to explain the thought process that went into making their pedigree.

**Professional Development**

The creative component I developed for the completion of UNI’s Masters in
Science Education was truly a compilation of everything I learned throughout the course
of the program and the essence of the teaching style I strive to achieve. Through this
project I have immersed myself in the principles of NGSS, the process of UbD, and
method of the EQUIP rubric. Familiarizing myself with these essential elements has
given me a better understanding for how students learn, how to better plan for learning
and how to evaluate those plans.

The research portion of this project taught me, not only how to research, but why
it is essential to being a quality teacher. This project brought to my attention numerous
resources that will be useful as a classroom teacher and also as a leader of the science
department. With the tools I have collected through this project, I feel confident that I can
successfully assist my colleagues through the upcoming transition to NGSS and the
inquiry based hands-on science style of teaching that compliments the new science
standards.

As this portion of my educational journey comes to an end, I look forward to
expanding my role not only within my school but also within the district. To do this, I
have taken on the position of science department head for the coming 2018-2019 school
year. I have additionally decided to continue participating in the District Science
Committee in order to further advance our science program. Lastly, I plan on taking the Advanced Placement course next summer so that my school can offer AP Biology in 2019-2020 school year.
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APPENDIX A
PROCESS OF CREATING UBD UNIT LESSONS

UbD: Stages of Backward Design
1. Identify desired results → CTS, Iowa Core Curriculum for Science, NGSS, KUDs, Essential Questions
2. Determine acceptable evidence → Formative and Summative Assessments Rubric
3. Plan learning experiences and instruction → Learning Cycle, Iowa Core ELA and Math

How to go about the UbD Process:
1. Unpack performance expectation – look at each word in the performance expectation and determine if it is skill or concept
   • Concepts (important nouns and noun phrases) are underlined and are what students need to KNOW and UNDERSTAND
   • Skills (verbs) are circled and are what students need to be able to DO and apply
2. KUD’s – take words underlined and circled and then create Knows, Understands, and Do’s. http://assessment.aaas.org/topics to help with writing them under the sub-ideas
   • Know – facts, vocabulary, formulas, prior (look through previous PE’s to see if terminology has been taught)
   • Do – what should students eventually be able to do as a result of the knowledge and skills acquired in the unit → Science & Engineering Practices are the Do’s (skills)
   • Understand – what will students need to understand/big concepts (Essential learning goals) by the end of the unit → DCI’s and Cross-Cutting Concepts are the Understands
3. CTS (Curriculum Topic Study)
   https://docs.google.com/a/uni.edu/document/d/1t4MJEMguF8chpCFXNLQWqjVDz9SVpsLgEFYw0qCKLb8/edit is the template
   • Complete 7 parts of CTS. Science Curriculum Topic Study book is used to see what pages and where to answer the 7 parts.
   https://docs.google.com/a/uni.edu/file/d/0B657HQBh2PHpbkJUYkVOeThWeGc/edit
1. SFAA http://www.project2061.org/publications/sf aa/online/sfaatoc.htm and Science Matter Book and AAAS http://assessment.aaas.org/topics to see misconceptions and how many based on grade have the misconception. Science Matters → use CTS Section 1B handout for page numbers
2. Instructional Implications for Benchmarks and NSES http://www.nap.edu/catalog.php?record_id=4962#
4. Benchmarks


7. CTS Updates to Framework on WEBSITE https://docs.google.com/a/uni.edu/file/d/0B657HQBh2PHpbkJUYkVOeThWeGc/edit

4. KUD revision – ensure KUD’s don’t need to change based on CTS

5. Writing Essential Questions
- Begin combining sub-units based on P.E and Crosscutting Concepts.
- Use “Framework for K-12 for Science Education Essential Questions” to see essential questions
- Things to consider when creating essential questions:
  - Have a relationship between ideas and helps us make sense out of confusing things
  - Asks for meaning, using reasoning, not recall
  - Isn’t googleable
  - Not a yes or no question/answer (open-ended/more than one answer) and is arguable
  - Uses prior knowledge to answer
  - Leads to more questions and provokes discussion
  - Uses analysis
  - Higher order questions
  - Relates to big idea
  - Gets revisited and recurs throughout one’s life
  - Sparks connections with prior learning and experiences
  - To the student, not the teacher
- Sites to help with Essential Questions
  1. essentialquestions.org → 25 Essential Questions and EQ Exchange
  2. July 15 – am – Framework for Science Ed. Essential Questions https://docs.google.com/a/uni.edu/file/d/0B657HQBh2PHpbkJUYkVOeThWeGc/edit
  3. bit.ly/gwiggins

- What’s the intent of the question? → Determines a successful question
- 2 types of Essential Questions
  - 1. Overarching
  - 2. Topics
- 2-5 E.Q. per unit is the recommendation
• Encourage “argument” and NOT “opinion” (Data + claim = argument)
6. For Probes for F.A. and Misconceptions – look at PE and U and D’s
   • [http://www.uncoveringstudentideas.org/science_tools](http://www.uncoveringstudentideas.org/science_tools) (tells us which Keely probes to use for which DCI)
   • [http://assessment.aaas.org/topics](http://assessment.aaas.org/topics)
   • Use Planning for a Pre-assessment for Readiness to identify student answers on probes, which in turn determines what type of knowledge they have and what they need to do next (similar to a rubric)
7. Devise summative assessment based on the P.E., understands, and do’s. Create rubrics for the assessment
8. Begin creating/compiling Learning Cycle lessons, keeping in mind the essential questions and your KUD’s
9. Create rubrics, keeping in mind the essential questions and your KUD’s
HS-LS3-3 Heredity: Inheritance and Variation of Traits. Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

<table>
<thead>
<tr>
<th>Know</th>
<th>Understand</th>
<th>Be Able to</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prior Vocabulary</strong>&lt;br&gt;• Chromosomes&lt;br&gt;• Meiosis&lt;br&gt;• Gametes&lt;br&gt;• Fertilization&lt;br&gt;• DNA&lt;br&gt;• Genes&lt;br&gt;• Proteins</td>
<td>• Genes code for proteins that produce a diverse range of traits&lt;br&gt;• The chromosome on which genes are located can affect the expression of traits&lt;br&gt;• Phenotype is affected by many different factors.</td>
<td>• Create data tables and graphs of frequency, distribution and variation of traits.&lt;br&gt;• Use statistics and probability to determine the relationship between a trait occurrence in a population and the influence of the environment&lt;br&gt;• Recognize patterns in data to predict changes in trait distribution within a population if environmental variables change&lt;br&gt;• Describe the expression of a chosen trait and its variation as causative or correlational to environmental factors based on reliable evidence (NGSS Evidence Statements, 2017)</td>
</tr>
<tr>
<td><strong>New Vocabulary</strong>&lt;br&gt;• Genetics&lt;br&gt;• Inherit&lt;br&gt;• Traits&lt;br&gt;• Purebred&lt;br&gt;• Cross&lt;br&gt;• Alleles&lt;br&gt;• Homozygous&lt;br&gt;• Heterozygous&lt;br&gt;• Genotype&lt;br&gt;• Phenotype&lt;br&gt;• Dominant&lt;br&gt;• Recessive</td>
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## APPENDIX C
CTS SUMMARY

### Summary for: HS-LS3-3 Heredity: Inheritance and Variation of Traits. Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

### Section 1: Adult content knowledge

**Science For All Americans** (Rutherford & Ahlgren, 1990)

- Offspring are very much like their parents but still show some variation.
- Offspring differ somewhat from their parent and from one another.
- Over many generations these differences accumulate to resulting in organisms that are very difference in appearance and behavior from distant relatives.
- Instructions for development are passed from parents to offspring in thousands of discrete genes.
- The sorting and combining of genes in sexual reproduction results in greater variety of gene combinations in the offspring of two parents.
- There are millions of different possible combinations of genes in the half apportioned into each separate sex cell, and there are also millions of possible combinations of each of those particular female and male sex cells.
- New mixes of genes are not the only source of variation in the characteristics of organisms.

### Section 2: Instructional Implications

- by the end of 10th grade, students should be able to know the following content

**Benchmarks for Science Literacy** (American Association for the Advancement of Science, n.d.)

- DNA provides for both the continuity of traits from one generation to the next and the variation that in time can lead to differences within a species and to entirely new species.
- Understanding DNA makes possible an explanation of such phenomena as the similarities and differences between parents and offspring, hereditary diseases, and the evolution of new species.
- This understanding also makes it possible for scientists to manipulate genes and thereby create new combinations of traits and new varieties of organisms.

**National Science Education Standards** (National Science Education Standards, 1996)

- In all organisms the instructions for specifying the characteristics of an organism is carried in DNA.
- Most of the cells in a human contain 22 pairs of autosomal chromosomes.
- Additionally, there is a pair of chromosomes that determines sex: a female
contains two X chromosomes and a male contain an X and a Y chromosome.

Section 3: Concepts and Specific Ideas

**Benchmarks for Science Literacy** (American Association for the Advancement of Science, 2009)

- Both genes and environment factors influence the rate and extent of development.
- The sorting and recombination of genes in sexual reproduction results in a great variety of possible gene combinations in the offspring of any two parents.
- Heritable characteristics can include details of biochemistry and anatomical features that are ultimately produced in the development of the organism. By biochemical and anatomical means, heritable characteristics may also influence behavior.

**National Science Education Standards** (National Science Education Standards, 1996)

- Transmission of genetic information to offspring occurs through egg and sperm cells that contain only one representative from each chromosome pair.
- The human body is formed from cells that contain two copies of each chromosome, and therefore, two copies of each gene, explains many features of human heredity, such as how variations that are hidden in one generation can be expressed in the next.

Section 4: Research on Student Learning

**Benchmarks for Science Literacy** (American Association for the Advancement of Science, 2009)

- Some students believe that traits are inherited from one parent.
- Some students believe that certain characteristics are always inherited from the mother and other traits only come from the father.
- Some students believe in blending of characteristics.
- Students may also believe that some environmentally produced characteristics can be inherited, especially over several generations.

**National Science Education Standards** (National Science Education Standards, 1996)

- Students struggle to grasp the connection between the occurrence of new variations in a population and the potential effect of those variations on long term survival of a species.
- Students may have the misconception of organisms developing new variations based on an organism's need, environment conditions, or use.

**Making Sense of Secondary Science** (Driver, Squires, Rushworth & Wood-Robinson 1994)

- Children tend to believe daughters inherit most traits from their mothers and sons inherit traits from their fathers.
- Students rarely applied the concept of chance and probability to the topic of inheritance.
- Students attribute variation to environmental factors alone.
• Sexual reproduction is usually not recognized as a source of variation.
• Large proportions of students do not understand the interaction of genes and the environment.

Section 5: Examination of Coherency and Articulation

Atlas of Science Literacy (American Association for the Advancement of Science, n.d.)
• The sorting and recombination of genes in sexual reproduction results in a greater variety of possible gene combinations of any two parents.
• The degree of relatedness between organisms or species can be estimated from the similarity of their DNA sequences, which often closely match their classification based on anatomical similarities.
• New heritable characteristics can result from new combinations of existing genes or from mutations of genes in reproductive cells.

Section 6: CTS Update from the Framework

• The information passed from parent to offspring is coded in the DNA molecules that form the chromosomes.
• In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis, creating new genetic combinations and thus more genetic variation.
• Mutations are a source of genetic variation.
• Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population.
APPENDIX D
PRE-ASSESSMENT

Name: ________________________  Period ________

Pre-Assessment Probe for HS-LS3-3: Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

Lucy and Maria Alymer are fraternal twins. Their father is white and their mother is half Jamaican. Which of the following statements best explains how this phenomena occurred?

a. Children inherit more traits from the father than from their mother

b. Children inherit half of their traits from the father and half from their mother

c. Male traits are stronger than female traits

d. The daughter with white features inherited more traits from her dad than the daughter with mixed race features

e. Parent’s traits don’t matter, the environment determines the person’s traits

f. A person’s traits are dependent on their blood type

(Mirror, 2015)
Scoring the Pre-Assessment

The purpose of this pre-assessment is to elicit student ideas on about heredity and inheritance and what students remember about meiosis and crossing over.

Addressing student responses:

The best answer should be answer b. Every parent contributes 50% of their genes and it is the interaction of those genes that determines an organism’s phenotype. Because of this, answer a and c are incorrect because those answers suggest that some genes are stronger or that one parent donates more than the other.

Answer e suggests that parental traits don’t matter and that the environment plays a larger role. The environment does play a role in the phenotype of an organism but the traits an organism displays in their phenotype are largely due to their genotype.

Answer f is wrong because blood type has nothing to do with a person’s phenotype and in fact a person’s blood type is determined by the traits inherited from their parents.
APPENDIX E
LESSON PLANS

Day 1: Pre-assessment

Learning Goal: Students will be able to explain that genes code for proteins which produce a diverse range of traits.

Success Criteria: Exit Slip

Plan for the day:

1. **Question of the Day (QOD):** Pre-assessment Lucy and Maria Alymer (Twins)
2. **Think, Pair, Share:** Answers to the pre-assessment
3. **Discussion:** Which do you think is the correct answer and why?
4. **Graphic Organizer:** Vocabulary terms
5. **Exit Slip:** Explain why you chose the answer you did for the QOD

Day 2 & 3: Engagement

Learning Goal: Students will be able to explain that genes code for proteins that produce a diverse range of traits.

Skill: Students will be able to create data tables and graphs of frequency, distribution and variation of traits.

Success Criteria: Exit Slip

Plan for the day:

1. **QOD:** Provide an example of a trait that you share with a member of your family.
2. **Activity:** Students will use PTC, Thiourea and Sodium Benzoate papers to test if they are tasters or non-tasters. Students will graph the results of their class.
3. **Activity:** Working in pairs, students will also graph and analyze other traits such as attached or free earlobes, widow’s peak vs. straight hairline and dimples vs no dimples.
4. **Exit Slip:** List one trait that can be passed on from parent to offspring (biological) and one trait that cannot be passed on from parent to offspring (non-biological, accent, hairstyle, etc).
5. **Differentiation:** Students with needs may graph fewer traits. Accelerated students may research another trait and include it in their graph.

Day 4: Explore
Learning Goal: Students will be able to explain that genes code for proteins that produce a diverse range of traits.

Success Criteria: Probability activity sheet

Plan for the day:

1. QOD: If you and your friend are playing rock, paper, scissors. What is the probability that your friend will choose rock? What is the probability that your friend will not choose rock?
3. Activity: Probability activity sheet
4. Differentiation: Students who are struggling with this review will have an opportunity to work with the instructional strategist to receive individual assistance.

Day 5: Explore

Learning Goal: Students will be able to explain that genes code for proteins that produce a diverse range of traits.

Success Criteria: Exit Slip

Plan for the Day:

1. QOD: Justin and Chelsey are parents to 4 girls. Chelsey is currently pregnant. What is the probability that this child will be a boy?
2. Research: Locating traits on chromosomes, genes, alleles, homozygous, heterozygous, dominant and recessive
3. Activity: Students will draw chromatids and identify a gene, alleles and explain if they are homozygous or heterozygous.
4. Exit Slip: Labeling alleles as heterozygous, or homozygous dominant or recessive.
5. Differentiation: Students who are struggling differentiating between this vocabulary terms will create a graphic organizer listing the vocabulary term and the definition.

Day 6: Explore

Learning Goal: Students will be able to explain that genes code for proteins that produce a diverse range of traits.
Success Criteria: Exit Slip

Plan for the day:

1. **QOD**: If brown eyes is dominant (AA) and blue eyes is recessive (aa), what color eyes will a person who is heterozygous (Aa) have?
2. **Graphic Organizer**: Phenotype vs. Genotype
3. **Activity**: Simple Genetics Practice Problems
4. **Differentiation**: Students who are struggling with this activity will have the opportunity to work in a small group setting with an instructional strategist.
5. **Exit Slip**: Explain the difference between genotype and phenotype.

Day 7: Explain

**Learning Goal**: Students will be able to explain that genes code for proteins that produce a diverse range of traits.

**Skill**: Use statistics and probability to determine the relationship between a trait occurrence in a population and the influence of the environment.

**Success Criteria**: Lab questions

Plan for the day:

1. **QOD**: If brown eyes is dominant (AA) and blue eyes is recessive (aa), what is the genotype and phenotype of someone who is heterozygous?
2. **Activity**: Mendelian Coin Flipping Lab
3. **Differentiation**: Students who are struggling with this lab will have the opportunity to work in a small group setting with an instructional strategist. Students who have mastered Punnett squares may do a webquest over the selective breeding of dogs.

Day 8: Explain

**Learning Goal**: Students will be able to explain that genes code for proteins that produce a diverse range of traits.

**Skill**: Use statistics and probability to determine the relationship between a trait occurrence in a population and the influence of the environment.

**Success Criteria**: Exit Slip

Plan for the Day:
1. **QOD:** What do the letters in a Punnett Square represent?

2. **Activity:** Punnett Square practice sheet

3. **Exit Slip:** Using a Punnett Square, answer the following question: In mice, black fur is dominant to white. A heterozygous black mouse is crossed with another heterozygous black mouse. What is the probability of their offspring having white fur?

4. **Differentiation:** Students who are struggling with this activity will have the opportunity to work in a small group setting with an instructional strategist. Students who excel at completing Punnett Squares will be challenged with completing a dihybrid Punnett Square.

**Day 9:** Explain

**Learning Goal:** The chromosome on which genes are located can affect the expression of traits

**Skill:** Use statistics and probability to determine the relationship between a trait occurrence in a population and the influence of the environment.

**Success Criteria:** Common Formative Assessment

**Plan for the Day:**

1. **QOD:** What numbers do you see? (Show Ishihara Image)
2. **Think, Pair Share:** Show graph of colorblindness in humans. Formulate an idea of why more males are colorblind than women?
3. **Show:** Karyotypes of a male and a female.
4. **Research:** What other traits are sex-linked?
5. **Practice:** Working in partners, students will complete the Sex-linked Inheritance Coin Flipping Lab
6. **Common Formative Assessment**
7. **Differentiation:** Students who do poorly on the common formative assessment will be given an opportunity to review and retake the common formative assessment.

**Day 10:** Explain

**Learning Goal:** The chromosome on which genes are located can affect the expression of traits.

**Skill:** Use statistics and probability to determine the relationship between a trait occurrence in a population and the influence of the environment.
Success Criteria: Lab Analysis questions

Plan for the day:

6. **QOD:** Write the genotypes for a mother with normal vision and father that is colorblind. Use the letter B to represent the alleles.
7. **Activity:** Finish the coin flipping lab. Create a data table and answer lab questions.
8. **Differentiation:** Students who are struggling with this lab will have the opportunity to work in a small group setting with an instructional strategist.

Day 11: Elaborate

**Learning Goal:** Phenotype is affected by many different factors.

**Skill:** Use statistics and probability to determine the relationship between a trait occurrence in a population and the influence of the environment.

**Success Criteria:** Activity Sheet

Plan for the day:

1. **QOD:** Why are males more likely than females to have sex-linked genetic disorders?
2. **Activity:** Group Jigsaw: Polygenic traits, incomplete dominance, codominance, and epistasis.
3. **Activity:** Activity sheet practicing incomplete dominance and codominance.
4. **Differentiation:** Students who are struggling with incomplete dominance will receive extra practice through a worksheet and may work in a small group setting with an instructional strategist. Students who excel will receive an activity sheet on blood and codominance.

Day 12: Elaborate

**Learning Goal:** Phenotype is affected by many different factors.

**Skill:**

- Describe the expression of a chosen trait and its variation as causative or correlational to environmental factors based on reliable evidence.
- Create data tables and graphs of frequency, distribution and variation of traits.
Success Criteria: Exit Slip

Plan for the day:

1. QOD: The four o’clock flower demonstrates incomplete dominance in petal color. Red petals are dominant to white petals. If you cross a red flower with a white flower, what color will their offspring be?
2. Activity: Discussion on the effect of the environment on phenotype.
3. Activity: Working in groups of two, students will complete a graphing activity on Sea turtles, temperature and sex determination.
4. Exit Slip: Describe how you would set up an experiment demonstrating the effect of temperature on sea turtle eggs.

Day 13: Elaborate

Learning goal: The chromosome on which genes are located can affect the expression of traits.

Skill: Use statistics and probability to determine the relationship between a trait occurrence in a population and the influence of the environment.

Success Criteria: Pedigree activity sheet

Plan for the day:

1. QOD: List one trait that can be influenced by the environment.
2. Think, pair share: Show students the pedigree of Queen Victoria’s family. Ask students to glean as much information from the chart as possible.
3. Activity: Activity sheet practicing labeling genotypes on pedigrees.
4. Differentiation: Students who are struggling with this activity will have the opportunity to work in a small group setting with an instructional strategist.

Day 14: Elaborate

Learning goal: The chromosome on which genes are located can affect the expression of traits.

Skill: Use statistics and probability to determine the relationship between a trait occurrence in a population and the influence of the environment.

Success Criteria: Autosomal vs. Sex-linked trait pedigree activity sheet

Plan for the day:
1. **QOD:** Show an example of a pedigree. Label the individual’s genotype.
2. **Think, pair share:** Show two different pedigrees, one autosomal, one sex-linked. Ask students to determine which is which with evidence to support their answer.
3. **Activity:** Autosomal vs. Sex-linked pedigrees activity sheet
4. **Differentiation:** Students who struggle completing this activity sheet will receive an additional/alternative activity in a small group setting with an instructional strategist.

**Day 15:** Evaluation

**Learning goal:** The chromosome on which genes are located can affect the expression of traits.

**Skill:** Use statistics and probability to determine the relationship between a trait occurrence in a population and the influence of the environment.

**Success Criteria:** Common Formative Assessment

**Plan for the day:**

1. **QOD:** Show an example of a pedigree. Ask students to determine whether the pedigree is representing an autosomal or a sex-linked trait.
2. **Common Formative Assessment**
3. **Activity:** Introduction of the creation of their own pedigree chart
4. **Differentiation:** Students who do not know or have contact with their immediate family may opt to use the people they consider their family or research a “celebrity” family.
5. **Differentiation:** Students who do poorly on the common formative assessment will be given an opportunity to review and retake the common formative assessment.

**Day 16:**

**Learning goal:** The chromosome on which genes are located can affect the expression of traits.

**Skill:** Use statistics and probability to determine the relationship between a trait occurrence in a population and the influence of the environment.

**Success Criteria:** Student creation of their own pedigree.

**Plan for the day:**
1. **QOD:** Show a pedigree. What is the probability that this individual has the trait?
2. **Activity:** Continue working on their own pedigree project

**Day 17:**

**Learning goal:** The chromosome on which genes are located can affect the expression of traits.

**Skill:** Use statistics and probability to determine the relationship between a trait occurrence in a population and the influence of the environment.

**Success Criteria:** Post Assessment

**Plan for the day:**

1. **QOD:** Show a pedigree. What is the probability that if these two individuals have a child, that child will have the disease?
2. **Activity:** Sharing of student pedigrees
3. Post Assessment and discussion
APPENDIX F
COMMON FORMATIVE ASSESSMENT

1. Which of the following is an example of a biological trait?
   A. personality
   B. hair style
   C. eye color
   D. regional accent

2. Mendel began his experiments with purebred pea plants. This approach enabled him to determine that variations among offspring were the result of:
   A. random mutations
   B. self-pollination
   C. genetic uniformity
   D. his crossings

3. A chart that traces the phenotypes and genotypes within a family is called a:
   A. pedigree
   B. karyotype
   C. Punnett square
   D. chromosome map

4. Which of the following conclusions was a result of Mendel's observations?
   A. Organisms that give rise to purebreds are genetically superior.
   B. Organisms that have intermediate features are self-pollinating.
   C. Organisms inherit two copies of each gene, one from each parent.
   D. Organisms that self-pollinate do not have "either-or" features.

5. Recessive alleles may not be expressed because they are:
   A. masked by a dominant allele.
   B. not a part of the chromosome
   C. the least common allele in a population.
   D. only found in every other generation
6. In the case of codominant alleles, a plant that is homozygous for red flowers that is crossed with a plant that is homozygous for white flowers will produce flowers that are

A. red and white spotted
B. completely white
C. dark pink all over
D. pink and red

7. Which of the following descriptions best matches the information shown in the diagram in Figure 6.1?

```
  S  s
 S  SS  Ss
 s  Ss  ss
```

A. a parental genotype that will be hidden in offspring
B. a parental phenotype that will be hidden in offspring
C. a phenotypic ratio of 1:2:1 for the offspring
D. a genotypic ratio of 1:2:1 for offspring

8. Most of the traits expressed in a person's phenotype are determined by:

A. Y chromosomes
B. X chromosome inactivation
C. autosomal chromosomes
D. sex chromosomes

9. A person who is heterozygous for a disorder caused by recessive alleles is a carrier of the disorder. A carrier is a person who:

A. does not have the disorder but can pass it on to offspring.
B. can develop the disorder later in life but cannot pass it on.
C. has a dominant normal allele that has been inactivated.
D. passes the disorder to offspring on the Y chromosome only.
10. Which of the following types of genetic information can be identified easily with a karyotype?

A. homologous chromosomes  
B. dominant traits  
C. phenotypic ratios  
D. recessive alleles

11. Which statement is true of a sex-linked recessive gene?

A. In a male, this recessive gene is always expressed.  
B. In a male, one copy is always inactivated.  
C. In a female, only one copy is needed for expression.  
D. In a female, the recessive gene is never expressed.

12. In the Punnett square in Figure 7.2, what do the letters R and r represent?

<table>
<thead>
<tr>
<th></th>
<th>R</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>RR</td>
<td>Rr</td>
</tr>
<tr>
<td>r</td>
<td>Rr</td>
<td>rr</td>
</tr>
</tbody>
</table>

FIG. 72

A. chromosomes  
B. alleles  
C. individuals  
D. chromatids

13. A plant that is homozygous for red flowers is crossed with a plant that is homozygous for white flowers. In the case of incomplete dominance, the flowers of the offspring will be

A. red and white  
B. white only  
C. pink only  
D. red only
14. What is the main difference between the carrier of a sex-linked disorder and the carrier of an autosomal disorder?

A. Female carriers of an autosomal disorder pass the disorder to all offspring.
B. All carriers of autosomal disorders have two dominant alleles for the disorder.
C. The carrier of a sex-linked disorder is always female but does not have the disorder.
D. Male carriers of a sex-linked disorder always have mothers who had the disorder.

15. Eye color, hair color, and skin color are polygenic traits. Polygenic traits result from:

A. recessive genes
B. many genes
C. codominant genes
D. epistatic genes

16. The Punnett square in Figure 7.1 shows a cross between two parents who have the genotype Ss for a genetic disorder caused by a recessive allele. Which of the following will have the genetic disorder?

<table>
<thead>
<tr>
<th></th>
<th>S</th>
<th>s</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
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<td>Ss</td>
</tr>
<tr>
<td>s</td>
<td>Ss</td>
<td>ss</td>
</tr>
</tbody>
</table>

FIG. 7.1

A. Ss parent
B. Ss offspring
C. SS offspring
D. ss offspring
Use the following illustration to answer questions 17 and 18. This illustration shows a family with royal hemophilia, which is a recessive, sex-linked trait.

17. What are the chances of Ken passing the hemophilia to his son?
A. 0%
B. 25%
C. 50%
D. 75%

18. What are the chances that Mary is a carrier for hemophilia?
A. 0%
B. 25%
C. 50%
D. 75%
APPENDIX G
ACTIVITY SHEETS

Name: ________________________ Date: ______________ Period: _____

Observing Human Traits Lab

How much do human traits vary within your class?

Traits are defined as physical characteristics that offspring inherit from their parents. In this lab, you will take an inventory of your observable traits and the observable traits of your classmates and compare the frequency of each trait.

Step 1: Observing your own traits

Working with a partner, decide which forms you have of each trait listed below. Circle the traits you have in the table below.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Form 1</th>
<th>Form 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTC</td>
<td>Taster</td>
<td>Non-taster</td>
</tr>
<tr>
<td>Sodium benzoate</td>
<td>Taster</td>
<td>Non-taster</td>
</tr>
<tr>
<td>Thiourea</td>
<td>Taster</td>
<td>Non-taster</td>
</tr>
<tr>
<td>Earlobes</td>
<td>Free</td>
<td>Attached</td>
</tr>
<tr>
<td>Dimples</td>
<td>Absent</td>
<td>Present</td>
</tr>
<tr>
<td>Hairline</td>
<td>Widow’s Peak</td>
<td>Straight</td>
</tr>
</tbody>
</table>

Step 2: Make predications

a. For the trait of earlobes only, predict how many students in your class do you think will share the same form (free or attached) as you? Explain your reasoning.

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

b. Do you think any of your classmates will have the same form of all the traits as you? If yes, predict how many of your classmates will the same form of all 6 traits as you.
**Step 3: Collect Class Data**

a. Record your results in the data chart your teacher has on the board. Then, record the results from the board into columns 2 and column 4 in the table below.

b. In column 3 and column 5, calculate the frequency of each form of the trait for your class using this formula: (number of students with form of trait / total number of students in the class) \times 100.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Number of students with Form 1</th>
<th>Frequency of students with Form 1</th>
<th>Number of students with Form 2</th>
<th>Frequency of students with Form 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTC</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Sodium benzoate</td>
<td></td>
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<tr>
<td>Thiourea</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Earlobes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dimples</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hairline</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Step 4: Graphing: Make a bar graph using the data from the graph above. Your graph should compare frequencies for each form of each trait. Put traits on the x-axis and frequency on the y-axis.
Step 5: Analyzing Data: Answer the following questions based on the data you collected.

6. For each trait, which form was the most common, Form 1 or Form 2?

__________________  ____________________
__________________  ____________________
__________________  ____________________

7. Why do you think one form is more common than the other?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

8. Do you think your classroom population is typical of a larger population such as your entire school or community? Explain your answer.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
Genetics Practice Problems

1. For each genotype, indicate whether it is **Homozygous dominant (HD)**, **Heterozygous (HE)**, **Homozygous recessive (HR)**.
   a. AA _________________
   b. Bb _________________
   c. cc _________________
   d. Dd _________________
   e. EE _________________
   f. Ff _________________
   g. Gg _________________
   h. Hh _________________

2. For each of the genotypes below, determine the phenotypes.
   **Purple flowers are dominant to white flowers**
   PP _________________
   Pp _________________
   pp _________________
   **Round seeds are dominant to wrinkled seeds**
   RR _________________
   Rr _________________
   rr _________________
   **Brown eyes are dominant to blue eyes**
   BB _________________
   Bb _________________
   Bb _________________

3. For each of the phenotypes listed below, write their genotypes.
   **Black fur is dominant to white fur.**
   Black fur _________________
   White fur _________________
   **Brown hair is dominant to blonde hair.**
   Brown hair _________________
   Blonde hair _________________
Punnett Square Practice

1. Green leaves are dominant to yellow leaves. Use the genotypes provided to complete the Punnett square and answer questions based on the Punnett square (2 points each).
   a. Gg x gg
      
      What percentage of the offspring will be green? _______

   b. Gg x Gg
      
      What percentage of the offspring will be green? _______

   c. GG x Gg
      
      What percentage of the offspring will be green? _______

   d. gg x gg
      
      What percentage of the offspring will be green? _______
Read the following word problems to determine the genotypes then use that information to complete the Punnett square and answer the questions (3 points each). *Show your work!*

2. A black chicken (BB) is crossed with a white chicken (bb). What percentage of their offspring will be black?

3. A black chicken (Bb) is crossed with another black chicken (Bb). What percentage of the offspring will be black?

4. A homozygous recessive white chicken is crossed with homozygous dominant black chicken. What percentage of the offspring will be white?

5. A homozygous recessive white chicken is crossed with a heterozygous black chicken. What percentage of the offspring will be white?

6. A heterozygous black chicken is crossed with a homozygous white chicken. What percentage of the offspring will be white?
Mendelian Genetics Coin Lab

**Objective:** Students will be able to explain that genes code for proteins that produce a diverse range of traits.

**Skill:** Calculating Probabilities

**Problem:** What is the probability that certain genotypes and phenotypes will occur?

**Materials:**
- 2 Pennies
- Masking Tape
- Marker

**Procedure:**
1. Using masking tape and a marker, label one penny with a capital A on one side and a lowercase a on the other side. This penny represents a pair of heterozygous genes from the mother. Do the same for the other penny. This penny represents a pair of heterozygous genes from the father.

2. Using a Punnett Square, cross the genes of the mother and father. Write the expected outcomes in the table below.

3. Next, flip the two coins simultaneously. The two coins together make up the genetic material of the zygote. Record the genotype of the offspring in the tally portion of the table below.

4. Repeat step 2 for a total of 50 trials. Calculate what percentage of “offspring” had each possible genotype and phenotype. Show your data and calculations to Mrs. Hogan or Mr. Decker.
## Analysis

1. How close did your actual results come to your expected results? If there was a significant difference, explain what you think caused the difference.

2. If you were to flip the coins one hundred times, would the results be similar or vastly different? Explain your reasoning.
Sex-Linked Inheritance Lab

The relationship between genotype and phenotype in sex-linked genes differs from that in autosomal genes. A female must have two recessive alleles of a sex-linked gene to express a recessive sex-linked trait. Just one recessive allele is needed for the same trait to be expressed in a male. In this lab, you will model the inheritance pattern of sex-linked genes.

**Problem:** How does probability explain sex-linked inheritance?

**Materials:**

- 2 Coins
- Masking Tape
- Sharpie Marker
- Index card with genetic cross (from Mrs. Hogan)

**Directions:**

1. Use the tape and marker to label two coins with the genetic cross shown on your group’s index card. One coin represents the egg cell and the other coin represents the sperm cell.
2. Flip the two coins and record the genotype of the “offspring”.
3. Repeat step 2 until you have modeled 50 genetic crosses. Make a data table to record each genetic cross that you model.
4. Calculate the genotype and phenotype probabilities for both males and females. Calculate the frequency of male offspring and female offspring.

**Questions:**

1. Do all of the females from the genetic cross show the recessive trait? Do all of the males show the recessive trait? Why or why not?
2. Make a Punnett square that shows the genetic cross. Do the results from your Punnett square agree with those from your experiment? Why or why not?
Incomplete dominance is a complex pattern of inheritance where neither trait is completely dominant or completely recessive. The heterozygous genotype is a blending of the two homozygous phenotypes.

Read the following problems and use a Punnett square to determine the phenotypes of the offspring.

1. In Betta fish, blue scales is dominant (BB) to yellow scales (bb). Using a Punnett square, cross a homozygous dominant Betta with a homozygous recessive Betta. What are the probabilities and colors of the offspring?

2. Using a Punnett square, cross a heterozygous Betta fish with a homozygous recessive Betta fish. What are the probabilities and colors of the offspring?

3. Using a Punnett square, cross a heterozygous Betta fish with another heterozygous Betta fish. What are the probabilities and colors of the offspring?

4. In snapdragon flowers, petal color is incompletely dominant. Red petals are dominant (RR) to white petals (rr). Using a Punnett square, cross a homozygous dominant flower with a homozygous recessive flower. What are the probabilities and colors of the offspring?

5. Using a Punnett square, cross a heterozygous flower with a heterozygous flower. What are the probabilities and colors of the offspring?
**Codominance** - When both alleles of a gene are expressed, this is called codominance. ABO blood types in humans are an example of codominance, meaning, type A blood and type B blood are dominant or type AB where both traits are fully and separately expressed. Type O blood is the recessive.

Read the following problems and use a Punnett square to determine the phenotypes of the offspring.

<table>
<thead>
<tr>
<th>Blood Type (Phenotype)</th>
<th>Genotype</th>
<th>Can donate blood to:</th>
<th>Can receive blood from:</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>ii</td>
<td>A,B,AB and O (universal donor)</td>
<td>O</td>
</tr>
<tr>
<td>AB</td>
<td>I^A^B</td>
<td>AB</td>
<td>A,B,AB and O (universal donor)</td>
</tr>
<tr>
<td>A</td>
<td>I^A^a or I^a^i</td>
<td>AB, A</td>
<td>O,A</td>
</tr>
<tr>
<td>B</td>
<td>I^B^B or I^b^i</td>
<td>AB,B</td>
<td>O,B</td>
</tr>
</tbody>
</table>

1. Write the genotype for each person based on the description below:
   a. Homozygous for the “B” allele
   b. Heterozygous for the “A” allele
   c. Type O
   d. Type AB
   e. Blood can be donated to anybody
   f. Can only get blood from a type “O” donor.

2. Mrs. Mathis is pregnant. Mr. Mathis is homozygous for type B blood. Mrs. Mathis is type “O”. Use the Punnett Square to determine all the possible blood types of their child.

```
+---+---+
|   |   |
|   |   |
+---+---+
3. Using a Punnett square, show all the possible blood types for the offspring produced by a type “O” mother and a type “AB” father. What are the probabilities of each blood type?

4. Mrs. Finkle has type “A” blood and Mr. Finkle is type “O”. They have three children named Ray, Louis, and Will. Ray is type “O” blood, Louis is type “A” and Will is type “AB”. Complete the Punnett square to determine the children’s genotype.

   a. List Mr. Finkle’s genotype: ______________
   b. List Mrs. Finkle’s genotype: _____________
   c. List Ray’s genotype: ___________________
   d. List Louis’ genotype: __________________
   e. List Will’s genotype: _________________
   f. Which child cannot be Mr. Finkle’s? Explain why.

   __________________________________________________________________________
   __________________________________________________________________________
Using a Punnett Square, determine the possible blood types of the offspring when the parents have the following blood types:

5. Father is type “A” homozygous and mother is type “B”, homozygous.

6. Father is type “O” and mother is type “AB”.

Determining the Sex of Sea Turtles Lab

The phenotype of offspring can be affected by many different factors, including the environment. In many reptiles, the sex of the offspring is influenced by the temperature at which the egg is incubated. In sea turtles, evidence suggests that eggs that mature at temperatures below 27.1°C result in all male turtles. In contrast, sea turtle eggs that mature at temperatures above 31°C will result in all female eggs. Numerous scientists have studied the effect of turtle eggs incubated in a range of temperatures between 27.1°C and 31°C has on the gender of the offspring. To do this, the scientists incubated different groups of sea turtle eggs at different temperatures. Each group contained 20 eggs. Below is the data the scientists have gathered.

**Purpose:**
To represent quantitative data through the use of a bar graph
To determine the effect temperature has on sea turtle sex determination

**Materials:**
Colored Pencils
Graph Paper

**Effect of Temperature on Sea Turtle Sex Determination**

<table>
<thead>
<tr>
<th>Incubation Temperature °C</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>27.0</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>27.5</td>
<td>18</td>
<td>2</td>
</tr>
<tr>
<td>28.0</td>
<td>14</td>
<td>6</td>
</tr>
<tr>
<td>28.5</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>29.0</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>29.5</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>30.0</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>30.5</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>31.0</td>
<td>0</td>
<td>20</td>
</tr>
</tbody>
</table>
Directions:

1. Construct a bar graph that represents the data in the table above. Be sure to label the X and Y axis.
2. Answer the analysis questions.

Analysis Questions:

1. Using the graph, describe the relationship between the incubation temperature and sex determination in sea turtles.

2. List the temperature that would produce a 1:1 ratio of female and male offspring in a group of sea turtle eggs. How did you determine this temperature?

3. List two factors that could affect the temperature that a nest of eggs incubate in.

4. If temperature affects the gender in reptile offspring, explain how climate change could affect reptile populations?
Pedigree Practice

A pedigree is a chart that can help trace the phenotypes and genotypes within a family to determine whether people carry recessive alleles. Autosomal pedigrees represent traits that are found on the autosomes, or the first 22 pairs of chromosomes. Use the autosomal pedigrees below to answer the questions.

1. In humans, left-handedness is a recessive trait. Given the following genotypes, describe the phenotypes (right or left-handed).

   AA= _____________________
   Aa=______________________
   aa= ______________________

2. Label the individual genotypes in the pedigree below.

3. How many children does this family have? _________ What are the sexes of the children? _________

4. Label the individual genotypes in the pedigree below.
5. How many children does this family have? _________ What are the sexes of the children? _________
6. Use the pedigree chart to answer the following questions about widow’s peaks. The widow’s peak gene controls whether a person has a widow’s peak or has a straight hairline. Having a widow’s peak is dominant to having a straight hairline, which is recessive. Place the genotypes of each individual below its symbol on the pedigree below.

7. How many family members have widow’s peaks?

8. What is the genotype of individuals 3 & 4?

9. Can either individual 8 or 9 be homozygous? Explain.

10. Explain the family relationship that individual 12 has with individual 2.

11. Use the following information to draw and label a pedigree: Jessica and Curtis have three children: Ty, Tiara, and Thomas. Thomas has Albinism, a recessive trait that causes lack of pigment in the skin and hair. Tiara married Luis and also had two children, Laura and John. John also has albinism. Luis’s brother Stephan also has albinism although Luis and Stephan’s parent did not have the disorder. Tiara is expecting another child. What is the probability that this child will have albinism as well?
Pedigree Practice: Sex-Linked Traits

Genes located on the sex chromosome require special consideration. Not only must you consider whether the trait is dominant or recessive but also how sex chromosomes are inherited. Recall that more males than females show a sex-linked trait in their phenotype and females can be carriers of sex-linked traits.

1. The following is a pedigree for color-blindness, a sex-linked trait. Label the genotypes for each individual in the pedigree. Remember, with sex-linked traits, X’s and Y’s must be included to indicate whether the individual is male or female.

2. Answer the questions based on the pedigree below.
Label the phenotypes (male/female, normal, carrier, colorblind) for the following individuals:

a. Individual 2 (Row II)? ________________ & ________________
b. Individual 4 (Row III)? ________________ & ________________
c. Individual 8 (Row IV)? ________________ & ________________

3. Is it possible for Individual 2 (Row IV) to be a carrier for colorblindness? Why?
   __________________________________________________________

4. Why does Individual 7 (Row IV) have colorblindness?
   __________________________________________________________

5. Why are all the daughters in Row II carriers for colorblindness?
   __________________________________________________________

**Autosomal or Sex-linked Challenge:** Compare the two pedigrees below. Write which pedigree represents an autosomal trait and which represents a sex-linked trait. Explain your reasoning.

**Autosomal or Sex-Linked? Explain your answer.**
   __________________________________________________________
   __________________________________________________________
   __________________________________________________________
   __________________________________________________________
   __________________________________________________________
Autosomal or Sex-Linked?

Explain your answer.

___________________________
___________________________
___________________________
___________________________
APPENDIX H

SUMMATIVE ASSESSMENTS

Name: __________________ Date: ___________ Period: ______

Pedigree Project

Objective: Students will be able to create a pedigree of family members using a trait of their choice.

Directions:

1. Begin drawing your pedigree.
   a. Be sure to include at least three generations (grandparent, great-grandparents, nieces, nephews).
   b. You will need to have at least 10 individuals in your pedigree.
   c. You can include whoever you see as your family in your pedigree.
   d. (Extra Credit, 5 points) Add a partner of your choice and produce a child between the two of you. Label your partner and child with names and the appropriate genotypes and phenotypes.
   e. If you would prefer to not do a pedigree of your family, you may also create a pedigree of a fictitious organism with a fictitious trait.

2. Choose one trait. Choose from one of the following listed below or you may choose a different trait. If you choose a trait that is not on the list, please get approval from me.
   a. Choose a trait that is easy to identify, write your trait on your pedigree.
   b. Use the appropriate symbols to represent the trait of each individual
   c. Label each individual with their name, their genotype and their phenotype.

3. Create a key
# List of Possible Traits

<table>
<thead>
<tr>
<th>Trait</th>
<th>Dominant</th>
<th>Recessive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimples</td>
<td>Dimples</td>
<td>No Dimples</td>
</tr>
<tr>
<td>Tongue Rolling</td>
<td>Roller</td>
<td>Non-Roller</td>
</tr>
<tr>
<td>Ear lobes</td>
<td>Unattached</td>
<td>Attached</td>
</tr>
<tr>
<td>Hair Line</td>
<td>Widow’s Peak</td>
<td>Straight Hair Line</td>
</tr>
<tr>
<td>Handedness</td>
<td>Right Handed</td>
<td>Left Handed</td>
</tr>
<tr>
<td>Freckles</td>
<td>Freckles Present</td>
<td>No Freckles</td>
</tr>
<tr>
<td>Hair Color</td>
<td>Dark Hair (Black, Brown)</td>
<td>Light (blond, red)</td>
</tr>
<tr>
<td>Hair Structure</td>
<td>Curly</td>
<td>Straight</td>
</tr>
<tr>
<td>Eye Color</td>
<td>Brown</td>
<td>Grey, Green, Hazel, Blue</td>
</tr>
<tr>
<td>Eye sight</td>
<td>Normal vision</td>
<td>Near-sightedness</td>
</tr>
</tbody>
</table>
Pedigree Symbols

Grading Rubric

<table>
<thead>
<tr>
<th>Criteria</th>
<th>10-8 Excellent</th>
<th>7-5 Good</th>
<th>4-2 Fair</th>
<th>1-0 Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedigree Individuals</td>
<td>Pedigree includes 10 or more individuals, and at least 3 generations.</td>
<td>Pedigree is missing 1 individual, has least 3 generations.</td>
<td>Pedigree is missing 2 individuals, only has 2 generations.</td>
<td>Pedigree is missing 3 or more individuals, only has 2 or less generations</td>
</tr>
<tr>
<td>Traits, symbols, and legend</td>
<td>Symbols are used correctly, each individual is labeled and the final product includes a legend.</td>
<td>1-2 symbols are incorrect, individuals are not labeled, includes a legend.</td>
<td>3-4 symbols are incorrect, individuals are not labeled, does not include a legend.</td>
<td>5 or more symbols are incorrect, individuals are not labeled, does not include a legend.</td>
</tr>
<tr>
<td>Appearance</td>
<td>Pedigree is neat in appearance. 1 or no spelling or grammatical mistakes</td>
<td>Pedigree is some neat. 2-3 Spelling or grammar mistakes.</td>
<td>Pedigree is not neat and contains 3-4 spelling or grammar mistakes.</td>
<td>Pedigree is not neat and contains 3-4 spelling or grammar mistakes.</td>
</tr>
</tbody>
</table>
Assessment Questions for HS-LS3-3: Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

Duchene’s muscular dystrophy is a sex-linked trait. A woman who is heterozygous for the disease marries a normal man.

a. What are the genotypes of the parents (1 point)?

b. Do the Punnett Square (1 point).

   ![Punnett Square]

   (Note: The Punnett Square should be filled in with the genotypes X-X, X-Y, Y-X, Y-Y, assuming the woman is X-Y and the man is X-Y, where X represents the normal allele and Y represents the disorder allele. The corners should show X-Y, X-Y, Y-Y, Y-Y.)

c. What is the probability that daughter will have Duchene’s (1 point)?

d. What is the probability that the son will have Duchene’s (1 point)?

   (Both should be calculated as 50% since they are X-Y combinations.)

e. Explain why males are more likely than females to have sex-linked genetic disorders (3 points).
1. In the following human pedigree, the filled symbols represent the affected symbols. You may assume that the disease allele is rare and therefore individuals marrying into the family are unlikely to have the defective allele (MIT, 2015).

(Massachusetts Institute of Technology, 2015)

- a. What is the most likely pattern of inheritance for this pedigree (1 point)?
- b. List the genotypes of individuals 1-5 using the letter “A”. (5 points).

<table>
<thead>
<tr>
<th>Individual</th>
<th>Genotype</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td></td>
</tr>
</tbody>
</table>

- c. If individuals #2 and 3 have another son what are the chances that this son will be affected (Show your work!).
APPENDIX I

UNIT PACING OF ACTIVITIES

<table>
<thead>
<tr>
<th>5E Learning Cycle Stage</th>
<th>Learning Activity</th>
<th>Description</th>
<th>Amount of Time Needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Assessment</td>
<td></td>
<td>Students will complete a probe assessing their knowledge traits, variation and inheritance.</td>
<td>Day 1:</td>
</tr>
<tr>
<td>Engage:</td>
<td>PTC paper strips</td>
<td>Students will use PTC paper to test if they are tasters or non-tasters.</td>
<td>Day 2:</td>
</tr>
<tr>
<td>Explore</td>
<td>Observing Human Traits</td>
<td>Students will collect data of the observable traits of their classmates.</td>
<td>Day 2 &amp; 3</td>
</tr>
<tr>
<td>Explore</td>
<td>Probability Review</td>
<td>Students will review the principles of probability and how they apply to genetics.</td>
<td>Day 4</td>
</tr>
<tr>
<td>Explore</td>
<td>Drawing and labeling of chromosomes.</td>
<td>Students will be able to differentiate between genes, alleles, chromosomes, heterozygous, homozygous and dominant and recessive.</td>
<td>Day 5</td>
</tr>
<tr>
<td>Explore</td>
<td>Mendelian coin flipping activity.</td>
<td>Students will be able to differentiate between genotype and phenotype.</td>
<td>Day 6</td>
</tr>
<tr>
<td>Explain</td>
<td>Punnett Square Practice</td>
<td>Students will practice using Punnett</td>
<td>Day 7 &amp; 8</td>
</tr>
<tr>
<td>Explain</td>
<td>Sex-Linked Traits Punnett square practice/ Coin flipping activity</td>
<td>Students will complete Punnett Squares using sex linked traits.</td>
<td>Day 9 &amp; 10</td>
</tr>
<tr>
<td>----------</td>
<td>---------------------------------------------------------------</td>
<td>---------------------------------------------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>Elaborate</td>
<td>Punnett Square practice with incomplete dominance, codominance</td>
<td>Students will identify complex patterns of inheritance and determine how phenotype is affected by many different factors.</td>
<td>Day 11</td>
</tr>
<tr>
<td>Elaborate</td>
<td>Effect of temperature on turtle eggs graphing lab</td>
<td>Students will use graphs to identify how the environment can affect physical traits.</td>
<td>Day 12</td>
</tr>
<tr>
<td>Elaborate</td>
<td>Pedigree Practice: Autosomal vs. Sex-linked traits</td>
<td>Students will identify different patterns of inheritance of traits through the use of pedigrees.</td>
<td>Day 13 &amp; 14</td>
</tr>
<tr>
<td>Evaluation</td>
<td>Creation of student pedigree</td>
<td>Students will create a pedigree of their family on a trait of their choice.</td>
<td>Day 15-17</td>
</tr>
</tbody>
</table>
Basic Probability Practice

1. How many pieces are there total in the spinner? __________

2. If you spun the spinner 1 time, what is the probability it would land on a gray piece? ________

1. If you spun the spinner 1 time, what is the probability it would land on a black piece? ________

2. If you spun the spinner 1 time, what is the probability it would land on a white piece? ________

3. If you spun the spinner 1 time, what is the probability it would land on a black or white piece? ________
4. If you were to roll a dice one time, what is the probability it will land on 3? ______________

5. If you were to roll a dice one time, what is the probability it will not land on a 2? __________

6. If you were to roll a dice one time, what is the probability it will land on a 4, 5, or 6? _______

7. How many shapes are there total in this array? _________

8. If you were to select 1 shape at random from the array, what is the probability it will be a circle? _____

9. If you were to select 1 shape at random from the array, what shape do you have the greatest probability of selecting? ___________

10. Which shape has a 32% chance of being selected? __________

11. Hailey and Dion are planning to have a child. What is the probability that this child will be a boy? _____

12. Hailey and Dion eventually had a boy. They would like to have a girl for their next child. What is the probability that their next child would be a girl? ______
13. Surprise! Their second pregnancy produced fraternal twins. What is the probability that the twins are one boy and one girl?
Sex-Linked Traits

In fruit flies, eye color is a sex-linked trait. Red are eyes are dominant to white eyes.

1. Identify the sexes and eye colors of the flies with the following genotypes:
   \[X^R X^r\] \[X^R Y\] \[X^r X^r\] 

   \[X^R X^R\] \[X^r Y\]

2. List the genotypes for the following flies’ phenotypes:
   - White-eyed, male ______________________
   - Red-eyed, female (heterozygous) __________
   - White-eyed, female ______________________
   - Red-eyed, male ______________________

3. Using a Punnett Square, show the cross of a white-eyed female \([X^r X^r]\) with a red-eyed, male \([X^R Y]\).

4. Using a Punnett Square, show a cross between a pure, red-eyed female and a white-eyed male.

   List the genotypes of the parents: ___________ & _________________
   What is the probability that their offspring will be:
   - White-eyed, male ______
   - White-eyed, female _____
Red-eyed, male _________
Red-eyed, female_______

5. Using a Punnett Square, show a cross between a red-eyed female (heterozygous) and a red-eyed male.

List the genotypes of the parents: ______________ & _______________

What is the probability that their offspring will be:

White-eyed, male ______
White-eyed, female _____
Red-eyed, male ________
Red-eyed, female_______

6. In humans, hemophilia is a sex-linked trait. Females can be carriers of the trait while males will either have the disease or not, but they cannot be carriers.

\[ X^H X^H = \text{Female, without Hemophilia} \]
\[ X^H Y = \text{Male, w/o Hemophilia} \]
\[ X^H X^h = \text{Female, Carrier} \]
\[ X^h Y = \text{Male, with Hemophilia} \]
\[ X^h X^h = \text{Female, with hemophilia} \]

Using a Punnett Square, show the cross for a man that has hemophilia with a woman who is a carrier for hemophilia:

What is the probability that any of their children will have the disease? ___________
7. Using a Punnett Square, show the cross for a woman who is a carrier and a normal man.

What is the probability their children will have hemophilia? What will the sex of that child with hemophilia be? ________________________________

8. Using a Punnett Square, show the cross for a woman who has hemophilia with a normal man. What is the probability their children will have hemophilia?

What is the sex of the children with hemophilia? __________________________

9. List the genotypes of the parent of the woman with hemophilia in problem 8 (her mother did not have hemophilia).
Name: ______________________  Date: ______________  Period: ______

Vocabulary Graphic Organizer

<table>
<thead>
<tr>
<th>Vocabulary Word</th>
<th>Definition</th>
<th>Sentence or Picture</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>
Selective Breeding Dogs Web quest

Dogs come in many shapes and sizes. How did this variety come about? In this Web quest you will learn about selective breeding. Use the internet to answer the following questions. Provide an example for each question.

1. How do dog breeders enhance certain traits?

2. How can breeding expose genetic disorders?

3. Choose a breed of dog and a trait of that dog. Explain how you might breed dogs to enhance that specific trait.
Dihybrid Cross

Corn is bred for traits that improve its usefulness for specific purposes. For example, it may be bred to grow in various climates, to produce more corn, or to have better taste. These traits depend on the alleles inherited by the corn plant. Suppose that you are studying the color and texture of kernels on a cob. Kernels can be either purple (R), which is the dominant color, or yellow, (r), which is the recessive color. Kernels can also be smooth (T), which is the dominant texture, or wrinkled (t), which is the recessive texture. In this activity, you will predict the inheritance of alleles for two particular traits in a dihybrid cross by using a Punnett Square.

**Problem:** What is the inheritance pattern for a dihybrid cross?

**Procedure:**

4. Suppose you want to cross two corn plants with the following genotypes: Plant A with RrTt and Plant B RrTT.
5. Use the Punnett square below to predict the possible genotypes of the offspring for this dihybrid cross.
6. To fill in the Punnett square, place the four combinations of Plant A’s alleles at the top of the Punnett square.
7. Place the four combinations of Plant B’s alleles on the left side of the Punnett square.

Example:

\[
\begin{array}{c|c|c|c|c}
& RY & Ry & rY & ry \\
\hline
RY & RRYY & RrYY & RrYy & RrYy \\
\hline
Ry & RrYy & rrYy & ryYy & ryYy \\
\hline
rY & RrYy & RrYy & RrYy & RrYy \\
\hline
ry & RrYy & RrYy & RrYy & RrYy \\
\end{array}
\]

RY, Ry, rY, ry (parent 1)

RY, Ry, rY, ry (parent 2)
8. Complete the Punnett square by crossing the alleles of the two plants.

![Punnett square diagram]

**Analyze and Conclude**

9. List the genotypes and phenotypes produced by this cross.

10. What is the genotypic ratio resulting from this cross? The phenotypic ratio?

11. If the genotypes for kernel texture of two plants are $tt$ and $tt$, what is the probability of their having offspring that have smooth kernels? Why?

12. Suppose corn plant C has a known genotype of RRTT. Could corn plants with cobs that had some yellow and wrinkled kernels be produced by crossing Plant C with a plant with a genotype of your choice? Why or why not?
Incomplete Dominance

Incomplete dominance is a complex pattern of inheritance where neither trait is completely dominant or completely recessive. The heterozygous genotype is a blending of the two homozygous phenotypes.

1. Explain the difference between incomplete dominance and codominance.

__________________________________________________________________
__________________________________________________________________
__________________________________________________________________

2. In Andalusian fowl (chickens) black feathers are dominant (BB) to the recessive white feathers (bb). The heterozygous results in a blue color feather. Cross a homozygous dominant chicken with a homozygous recessive chicken. Complete the Punnett Square. What is the probability of each color appearing in the offspring?

3. Cross a heterozygous chicken with another heterozygous chicken. Complete the Punnett Square. What is the probability of each color appearing in the offspring?
Codominance and Blood Type

When both alleles of a gene are expressed, this is called codominance. ABO blood types in humans are an example of codominance, meaning, type A blood and type B blood are dominant or type AB where both traits are fully and separately expressed. Type O blood is the recessive.

Use the information in the chart to help answer the following questions.

<table>
<thead>
<tr>
<th>Blood Type (Phenotype)</th>
<th>Genotype</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>ii</td>
</tr>
<tr>
<td>AB</td>
<td>I^A^B</td>
</tr>
<tr>
<td>A</td>
<td>I^A or I^i</td>
</tr>
<tr>
<td>B</td>
<td>I^B or I^i</td>
</tr>
</tbody>
</table>

4. It is 1967 (prior to DNA fingerprinting) and two parents think their baby was switched at birth. The mom has blood type “O”, the father has blood type “AB”.

a. a. Mom’s genotype ______________
b. b. Father’s genotype ____________
c. c. Baby’s genotype
   ____________
d. d. Complete the Punnett square to determine all the possible genotypes produced by this couple.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

 e. e. Was the baby switched? ______________
5. A mother came on the Maury show and wanted to know who the father of her child was. Based on the information in the table below, which men could be the father of the baby.
(hint: look at the baby’s blood type first)

<table>
<thead>
<tr>
<th>Name</th>
<th>Blood Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mother</td>
<td>Type A</td>
</tr>
<tr>
<td>Baby</td>
<td>Type B</td>
</tr>
<tr>
<td>The Mailman</td>
<td>Type O</td>
</tr>
<tr>
<td>The Butcher</td>
<td>Type AB</td>
</tr>
<tr>
<td>The Waiter</td>
<td>Type A</td>
</tr>
<tr>
<td>The Cable Guy</td>
<td>Type B</td>
</tr>
</tbody>
</table>
Pedigree Practice

A pedigree is a chart that can help trace the phenotypes and genotypes within a family to determine whether people carry recessive alleles.

14. Brown hair is a dominant trait while red hair is recessive. Label the genotypes of individuals in the autosomal pedigree below.

15. Baldness is a sex-linked, recessive trait. Label the genotypes of the individuals in the pedigree below and answer the following questions based on the pedigree.

a. Explain how individual 5 got the trait of baldness?

b. Is it possible for individual 15 to be a carrier of the baldness trait? Explain your answer.
c. Individual 10 marries a woman that is a carrier for the trait of baldness. What is the probability that their daughters will be bald? What is the probability that their sons will be bald?
**APPENDIX K**

**EQUIP RUBRIC**

<table>
<thead>
<tr>
<th>Lesson and Unit Criteria</th>
<th>Specific evidence from materials (what happened/where did it happen) and reviewer's reasoning (how/why is this evidence)</th>
<th>Evidence of Quality?</th>
<th>Suggestions for improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Explaining Phenomena/Designing Solutions: Making sense of phenomena and/or designing solutions to a problem drive student learning.</td>
<td>The lesson started with a great phenomena that grabbed students' attention and made them ask lots of questions. They asked about checking the twins DNA but were uncertain how to design a solution.</td>
<td>None</td>
<td>I should have referred more often to the phenomena throughout the entire unit.</td>
</tr>
<tr>
<td>B. Three Dimensions: Builds understanding of multiple grade-appropriate elements of the science and engineering practices (SEP), disciplinary core ideas (DCI), and crosscutting concepts (CCC) that are deliberately selected to aid student sense-making of phenomena and/or designing of solutions.</td>
<td>Document evidence and reasoning, and evaluate whether or not there is sufficient evidence of quality for each dimension separately</td>
<td>None</td>
<td>There was not a lot of opportunity for designing solutions.</td>
</tr>
<tr>
<td>I. Provides opportunities to develop and use specific elements of the SEP(s).</td>
<td>The opening phenomena allowed students to ask questions and solve problems. The use of Punnett square and pedigrees asked students to use mathematics and model. The lesson on sea turtles and cloning traits gave students an opportunity to analyze and interpret data and engage in argumentation.</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>II. Provides opportunities to develop and use specific elements of the DCI(s).</td>
<td>Students used Punnett squares and pedigrees to account for variation within a population. In addition to these activities, students studied various complex patterns of heritabilities such as incomplete and co-dominance and sex-linked traits.</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>III. Provides opportunities to develop and use specific elements of the CCC(s).</td>
<td>The cross-cutting concept of patterns was emphasized throughout the practice of Punnett squares and pedigrees and in observing traits. Cause and effect was also discussed during the Sea Turtle activity.</td>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>
### 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 DCRs.

Students asked questions during the phenomena portion of the unit. The analyzed and interpreted data in the Observing Human Traits lab and again in the Determining Sex in Sea Turtles lab. The lab also emphasized the cross-cutting concept of cause and effect. Students also identified patterns in data in the Sea Turtles lab and in the Punnett square activity sheets. All of the activities support the DCI of Inheritance of traits and Variation of Traits.

<table>
<thead>
<tr>
<th>Rating for Category I, NGSS 3D Design—lesson</th>
<th>Lesson Rating scale for Category I (Criteria A–C only):</th>
</tr>
</thead>
<tbody>
<tr>
<td>After carefully weighing the evidence, reasoning, and suggestions for improvement, rate the degree to which there is enough evidence to support a claim that the lesson meets these criteria.</td>
<td></td>
</tr>
<tr>
<td>Lesson Rating scale for Category I (Criteria A–C only):</td>
<td></td>
</tr>
<tr>
<td>3: Extensive evidence to meet at least two criteria (and at least adequate evidence for the third)</td>
<td></td>
</tr>
<tr>
<td>2: Adequate evidence to meet at least three criteria in the category</td>
<td></td>
</tr>
<tr>
<td>1: Adequate evidence to meet at least one criterion in the category, but insufficient evidence for at least one other criterion</td>
<td></td>
</tr>
<tr>
<td>0: Inadequate (or no) evidence to meet any of the criteria in the category</td>
<td></td>
</tr>
</tbody>
</table>

#### What’s next if the lesson rating is less than a 2?

If the rubric is being used to approve or vet resources and the lesson or unit does not score at least a “2” in Category I: NGSS 3D Designed, the review should stop and feedback should be provided to the lesson developer(s) to guide revisions. If the rubric is being used locally for revising and building lessons, professional judgment should guide whether to continue reviewing the lesson. Categories II and III may be time consuming to evaluate if Category I has not been met and the feedback may not be useful if significant revisions are needed in Category I, but evaluating these criteria in a group may support deeper and more common understanding of the criteria in these categories and more complete feedback to the lesson developer (if they are not in the room) so that Categories II and III are more likely to be met with fewer cycles of revision.

#### What’s next if the lesson rating is a 2 or 3?

If you are evaluating a lesson that shows sufficient evidence of quality to warrant a rating of either a 2 or a 3 for Category I, proceed to Category II: NGSS Instructional Supports.
## Category I: NGSS 3D Design (additional criteria for units only):

If you are evaluating a lesson, it is not necessary to evaluate criteria D–F. Please enter your rating for a single lesson above (after C).

<table>
<thead>
<tr>
<th>Unit Criteria</th>
<th>Specific evidence from materials and reviewers’ reasoning</th>
<th>Evidence of Quality?</th>
<th>Suggestions for improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>A unit or longer lesson designed for the NGSS will also include clear and compelling evidence of the following:</td>
<td>Students had the opportunity to assess their observable traits and compare them to others in the room and in the world. This led to students asking why some people have the traits and others do not. We then built on those questions using mathematics and probability and discussed actual vs. expected outcomes. Students also asked if a trait is present in a family, how is that not all family members get that trait. To answer this, Punnett squares were used along with terms such as homozygous dominant, recessive and heterozygous to help explain. We then incorporated gene location and expression as a factor in appearance of a trait. Students then explored their understanding by contemplating how the environment can influence phenotype as well.</td>
<td>None</td>
<td>Students had some questions but I feel like I should have provided more time for students to come up with more questions as it may have guided the lesson better.</td>
</tr>
<tr>
<td>D. Unit Coherence: Lessons fit together to target a set of performance expectations.</td>
<td>Climate change and its effects were discussed during the sea turtle activity. Students also used the concept of patterns in data from the observation of traits activity and the sea turtles activity. Causes and effects of climate change on reptiles was also a cross-cutting concept in this lesson.</td>
<td>None</td>
<td>I think I need more DCI’s related to physical and earth science as I only have one. However, I am not sure how to incorporate those into this particular lesson.</td>
</tr>
<tr>
<td>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.</td>
<td>Math was incorporated throughout the lesson through the concepts of probability, expected vs. actual outcomes and the creation and interpretation of graphs. Students also had many writing opportunities through the answering questions, the writing of sentences using vocabulary terms, and summarizing the days lesson through exit slips.</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>ii. The lessons help students develop toward proficiency in a targeted set of performance expectations.</td>
<td></td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>E. Multiple Science Domains: When appropriate, links are made across the science domains of life science, physical science and Earth and space science.</td>
<td></td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>i. Disciplinary core ideas from different disciplines are used together to explain phenomena.</td>
<td></td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>ii. The usefulness of crosscutting concepts to make sense of phenomena or design solutions to problems across science domains is highlighted.</td>
<td></td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>F. Math and ELA: Provides grade-appropriate connection(s) to the Common Core State Standards in Mathematics and/or English Language Arts &amp; Literacy in History/Social Studies, Science and Technical Subjects.</td>
<td></td>
<td>None</td>
<td></td>
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</tbody>
</table>

**Rating for Category I: NGSS 3D Design—units**

After carefully weighing the evidence, reasoning, and suggestions for improvement, rate the degree to which the criteria are met across the unit.

**Unit Rating Scale for Category I (Criteria A–F):**

1. At least adequate evidence for all 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
3. Adequate evidence for some criteria in Category I, but inadequate/no evidence for at least one criterion A–C
4. Inadequate (or no) evidence to meet any criteria in Category I (A–F)

**Select Rating**

![Rating Scale](image)
### DNA, Genes, and the Expression of Those Genes

DNA, genes, and the expression of those genes are all topics that are supposed to be covered according to NGSS and the Iowa Core at the high school level. The skills of creating and analyzing the information from a Punnett square and a pedigree are also expectations of the NGSS and the Iowa Core.

### Differentiated Instruction

**D. Scientific Accuracy**: Uses scientifically accurate and grade-appropriate scientific information, phenomena, and representations to support students’ three-dimensional learning.

**E. Differentiated Instruction**: Provides guidance for teachers to support differentiated instruction by including:

1. Appropriate reading, writing, listening, and/or speaking alternatives (e.g., translations, picture support, graphic organizers, etc.) for students who are English language learners, have special needs, or read well below the grade level.
2. Extra support (e.g., phenomena, representations, tasks) for students who are struggling to meet the targeted expectations.
3. 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.

Students were provided with graphic organizers for all writing assignments. Students were also provided with alternative or additional assignments if they required extra help. Materials for accelerated students was also included in the lesson plan.

I did not have the activities and labs translated for any ELL students.

### Rating for Category II: Instructional Supports—lessons

After carefully weighing the evidence, reasoning, and suggestions for improvement, rate the degree to which the lesson met this category.

If you are evaluating an instructional unit rather than a single lesson, continue on to evaluate criteria F-G and rate Category II overall below.

Lesson Rating Scale for Category II (Criteria A-E only):

1. 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 four criteria, including A
3. Adequate evidence of quality for at least two criteria in the category
4. Adequate evidence of quality for no more than one criterion in the category

Select Rating

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>
**Category II: NGSS Instructional Supports (additional criteria for units only)**

If you are evaluating a lesson, it is not necessary to evaluate criteria F–G. Please enter your rating for a lesson above after F.

<table>
<thead>
<tr>
<th>Unit Criteria</th>
<th>Specific evidence from materials and reviewers' reasoning</th>
<th>Evidence of Quality?</th>
<th>Suggestions for improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>A unit or longer lesson designed for the NGSS will also include clear and compelling evidence of the following:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F. Teacher Support for Unit Coherence: Supports teachers in facilitating coherent student learning experiences over time by:</td>
<td>Almost everyday an exit question was given to students to assess what they had learned. This method of informal assessment led to new questions that required me to adjust upcoming lessons. Activities such as graphing and using models such as Punnett squares and pedigrees allowed students to see mathematical patterns in the inheritance of traits and helped them to make sense of why certain traits are expressed or not.</td>
<td>None □ Inadequate □ Adequate □ Extensive</td>
<td>Provide more opportunities for students to ask questions.</td>
</tr>
<tr>
<td>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.).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ii. Providing strategies for ensuring student sense-making and/or problem-solving is linked to learning in all three dimensions.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>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.</td>
<td>The unit is structured in a way that gradually shifts the responsibility of learning from teacher to student. As an example, students are working closely with each other and the teacher at the beginning of the lesson to learn how to perform Punnett squares and to relate probability to those Punnett Squares. Students also needed help at the beginning of the unit creating graphs for the observing traits unit but by sea turtles activity they made their own graph with very little teacher involvement. Also by the end of the unit, students are creating pedigrees on their own.</td>
<td>None □ Inadequate □ Adequate □ Extensive</td>
<td></td>
</tr>
</tbody>
</table>

**Rating for Category II: NGSS Instructional Supports—units**

After carefully weighing the evidence, reasoning, and suggestions for improvement, rate the degree to which the criteria are met across the unit.

**Unit rating scale for Category II (Criteria A-G):**

1. Adequate evidence for at least three criteria in the category
2. Some evidence for all criteria in the category and adequate evidence for at least five criteria, including A
3. At least adequate evidence for all criteria in the category; extensive evidence for at least two criteria
4. Adequate evidence for no more than two criteria in the category

**Select Rating**

0 1 2 3
### Category III: Monitoring NGSS Student Progress (lessons and units)

The lesson/unit supports monitoring student progress in all three dimensions of the NGSS as students make sense of phenomena and/or design solutions to problems.

<table>
<thead>
<tr>
<th>Lesson and Unit Criteria</th>
<th>Specific evidence from materials and reviewers’ reasoning</th>
<th>Evidence of Quality?</th>
<th>Suggestions for improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Monitoring student performance: 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.</td>
<td>Students performed authentic labs, such as the Observable Human Traits lab, where data was collected, graphs were made and analyzed. Students used math, probability and Punnett squares to make predictions about the expression of traits.</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>8. Formative: Embeds formative assessment processes throughout that evaluate student learning to inform instruction.</td>
<td>Daily entrance and exit slips, practice activities, common formative assessments were embedded throughout the unit.</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>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.</td>
<td>The Pedigree project includes a rubric.</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>D. Unbiased tasks/items: Assesses student proficiency using methods, vocabulary, representations, and examples that are accessible and unbiased for all students.</td>
<td>The unit includes vocabulary practice in the activities such as the graphic organizer that asks students to define the term and use it in a sentence or draw a picture. In the Genetic Practice problems activity students had an opportunity practice using vocabulary terms such homozygous, recessive, dominant and heterozygous.</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

**Rating for Category III, Monitoring NGSS Student Progress—lessons**

After carefully weighing the evidence, reasoning, and suggestions for improvement, rate the degree to which the lesson met this category.

- Select Rating

If you are evaluating an instructional unit rather than a single lesson, continue on to evaluate criteria E–F and rate Category III overall below.

**Lesson Rating scale for Category III (Criteria A–D only):**

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 three criteria, including A

1: Adequate evidence for at least two criteria in the category

0: Adequate evidence for no more than one criterion in the category
### Category III: Monitoring NGSS Student Progress (additional criteria for units only)

If you are evaluating a lesson, it is not necessary to evaluate criteria 6–7. Please enter your rating for a lesson above (after 0).

<table>
<thead>
<tr>
<th>Unit Criteria</th>
<th>Specific evidence from materials and reviewers’ reasoning</th>
<th>Evidence of Quality?</th>
<th>Suggestions for improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>E. Coherent Assessment system: includes pre-, formative, summative, and self-assessment measures that assess three-dimensional learning.</td>
<td>The unit included a pre-assessment, formative assessments in the form of entrance and exit slips, questions scattered throughout the lesson and a common formative assessments in the form of multiple choice questions. A summative assessment pedigree project was also given.</td>
<td>None</td>
<td>Extensive</td>
</tr>
<tr>
<td>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</td>
<td>Many opportunities are present in this unit in the form of labs, practice worksheets. Examples are: Observing Human Traits lab, Probability practice, Mendelian Coin Lab, Genetics Practice Problems, Punnett Square practice, Complex Inheritance Problems, Sex-linked traits lab, Pedigree practice, Determining Sex in Sea Turtles Lab and the Pedigree Project.</td>
<td>None</td>
<td>Extensive</td>
</tr>
</tbody>
</table>

**Rating for Category III: Monitoring NGSS Student Progress—units**

After carefully weighing the evidence, reasoning, and suggestions for improvement, rate the degree to which the criteria are met across the unit.

<table>
<thead>
<tr>
<th>Unit Rating scale for Category III (Criteria A–F):</th>
</tr>
</thead>
<tbody>
<tr>
<td>3: At least adequate evidence for all criteria in the category; extensive evidence for at least one criterion</td>
</tr>
<tr>
<td>2: Some evidence for all criteria in the category and adequate evidence for at least five criteria, including A.</td>
</tr>
<tr>
<td>1: Adequate evidence for at least three criteria in the category</td>
</tr>
<tr>
<td>0: Adequate evidence for no more than two criteria in the category</td>
</tr>
</tbody>
</table>

**Select Rating**

0 1 2 3
## Category Ratings:

Transfer your team’s ratings from each category to the following chart and add the scores together for the overall score:

<table>
<thead>
<tr>
<th>Category I: NGSS 3D Design</th>
<th>Category II: NGSS Instructional Supports</th>
<th>Category III: Monitoring NGSS Student Progress</th>
<th>Total Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 1 2 3</td>
<td>0 1 2 3</td>
<td>0 1 2 3</td>
<td>7</td>
</tr>
</tbody>
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### Overall ratings:

The score total is an approximate guide for the rating. Reviewers should use the evidence of quality across categories to guide the final rating. In other words, the rating could differ from the total score recommendations if the reviewer has evidence to support this variation.

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 “4–5”)

N: Not ready to review—Not designed for the NGSS; does not meet criteria (total “0–3”)