Incorporating Biotechnology into the Classroom: Teaching content areas using biotechnology and industry connections. Unit Plan

Unit Introduction: This unit studies the questions: “What is natural selection and why is natural selection the driving force of biological evolution”. Through the study of genetics and biotechnology, this unit will look at what factors influence species’ survivability as well as the evolution of populations and speciation.

This general 10th grade biology course strives to teach students how to think for themselves, sift through information, come up with hypotheses, back them up with data, and put the scientific inquiry skills to use in other problem solving situations. The course is designed to introduce students to: the study of living organisms, the environment, ecological concerns, animal diversity, living cells, biological evolution, the interdependence of organisms, genetics, biotechnology, ethics, and the energy use of organisms.

Time Frame: Thirty class periods, 45 minute class periods (to be interwoven throughout the first semester of biology) and one day for field trip to the Arizona Museum of Natural History.

Unit Outline:
Lesson 1: Cube Activity and “What is Science” Activity
Lesson 2: Alike, but not the Same Activity: Intro to Genomics
Lesson 3: Constructing a Paper Helix
Lesson 4: The Size of the Genome Activity
Lesson 5: Gel Electrophoresis of Dyes Lab
Lesson 6: DNA Extraction from Fruits
Lesson 7: DNA Fingerprinting Lab
Lesson 8: Microarray Lab
Lesson 9: Pre-Field Trip Lesson Plan Classification Systems: Classifying Foam Shapes
Lesson 10: Field Trip Lesson Plan: Preparation and the Arizona Museum of Natural History Field Trip
Lesson 11: Post Field Trip

Grade Levels: 10th grade

Subject/Topic Areas: Natural Selection and Biological Evolution
Genotypic and Phenotypic Variations
Environmental Factors
Fossil Records
Biological Classification Systems

Unit Designer: Trish Bryant Smith

School District: Chino Valley Public School District #51
School: Chino Valley High School, Chino Valley, Arizona

IDENTIFY DESIRED RESULTS
What enduring understandings are desired?
1. Genotypic variation occurs and results in phenotypic diversity, which can result in adaptations that influence an organism’s success in an environment.
   AZ State Standard: Strand 4, Concept 4, PO 2.
2. Natural selection is the driving force for biological evolution.
   AZ State Standard: Strand 4, Concept 4, PO 3.
3. The fossil record along with nuclear chemistry, geology, molecular biology, geographical distribution, and DNA analysis give support to the theory of evolution through natural selection.

**AZ State Standard: Strand 4, Concept 4, PO 5.**

**Behavioral Objectives: TSW**

1. Analyze the importance of finding evidence to help support the understanding of important concepts
2. Design and conduct an experiment using scientific inquiry skills.
3. Analyze data from experimentation and appropriately communicate the findings.
4. Explain how genotypic variation occurs and why it can result in phenotypic diversity.
5. Identify different components of natural selection
6. Explain how natural selection is the driving force behind biological evolution.
7. Explain how genotypic and phenotypic variation can result in adaptations that influence a species success in an environment.
8. Analyze patterns in the fossil record, nuclear chemistry, geology, molecular biology, geographical distribution and DNA analysis which give support to the theory of biological evolution through natural selection resulting in the present day biodiversity.
9. Utilize different methods of classification systems to determine the relatedness among various species.
10. Design a cladogram comparing the degree of relatedness among six dinosaurs, six birds, and six reptiles
11. Become proficient in different biotechnology techniques.

2–6 are adapted from the Arizona Science Standard Performance Level Descriptors for High School.

What essential questions will guide this unit and focus teaching and learning?

**Essential Questions:**

1. How is natural selection an underlying force of Biological Evolution?
2. How does genetic research support the patterns in the fossil record, giving support to the theory of Biological Evolution?
3. How has biotechnology changed science and led to the formation of new species?
4. Is genetic engineering a form of natural selection?
5. Have bacteria that are resistant to antibiotics been naturally selected?
6. Are dinosaurs, in fact, more related to birds than reptiles?

The next chart is a tentative outline of when to teach the lessons focusing on Biological Evolution and the use of biotechnology to teach those lessons. The sequence starts at the beginning with what science is and moves on through a series of activities ending with analyzing different fish proteins for the degree of relatedness among the different species of fish tested. The activities are only mapped out for the first 10 weeks of the semester. Obviously, due to different needs of different classes, the activities may be changed around and spread throughout the first semester or even year depending upon the needs of the students. The chart is meant to be used in conjunction with the rest of the unit plan for continuity.
Unit 3: Lesson 1: 1st Week: Cube Activity and “What is Science” Activity

Time Planned for activities: one class period (50 minutes)

Student Prior Knowledge: None

Knowledge Gained from Lesson:
- What science is and what science is not.
- A basic comprehension of the skills used in science.

General Concepts:
The students will be working with the scientific inquiry skills all year.

Arizona Standards:
Science Standards
Strand 1: Concept 1: PO1 & PO4

NSEs:
Science as Inquiry NSES p.175

Referenced Common Misconceptions:
“Although most students believe that scientific knowledge changes, they typically think changes occur mainly in facts and mostly through the invention of improved technology for observation and measurement. They do not recognize that changed theories sometimes suggest new observations or reinterpretation of previous observations.” (Benchmarks, pg. 332)

Essential Questions:
What is science?
How are the process skills of science used in everyday life?

Student Behavioral Objectives:
- Student will identify what is science and what is not.
- Student will conclude that the process skills in science are useful for more problems than just a science fair project.

Description of the lab:
The cube activity (Bybee’s boxes) is an introduction to inquiry where students practice observations, inferences, and making claims based on evidence. The “What is Science” activity is where students begin to realize the difference between science as a way of knowing and other ways of knowing. Students are confronted with statements that are either scientific, pseudoscientific, or not scientific. Students practice communicating their ideas about each statement using evidence and their understanding of science.

Inquiry: 2 (Teacher generated question)
Work in groups of 2 to 3 students.

Materials:
Paper cubes, examples of science facts and science theories versus non-scientific “facts” and non-scientific “theories”, read protocol for complete materials list.
Safety Considerations: None

Assessments:

Pre-assessment: on the scientific inquiry skills – paper quiz.

Participation:
Question and answer session.
Performance base: during and after the lesson, how the students come to their conclusions.

Real world connections: Examples of science and pseudo science articles that have been published or are in the news.

Unit 3: Lesson 2: 2nd Week: Alike, but not the Same Activity: Intro to Genomics (Activity 1 in Relating Genetics to Everyday Life book)

Time Planned for activities: two class periods (50 minutes each): 1 class period to do activity, the other to do graphs and data analysis

Student Prior Knowledge:
Preferably the knowledge of how to make graphs, but not entirely necessary.

Knowledge Gained from Lesson:
- The students will distinguish between genotypes and phenotypes.
- Students will determine the various factors of genetic variability and how that leads to a species’ survivability.
- Students will produce an easy to comprehend graph of the class results.

Concepts to be covered after this lesson:
- The students will be working with genetic variability all year.
- The students will be leading up to natural selection and Biological Evolution.

Arizona Standards:
Science Standards
Strand 4: Concept 2: PO3
Concept 4: PO2
Strand 1: Concept 2: PO5
Concept 4: PO2

NSES
Science as Inquiry NSES p.175
Life Science
The molecular basis of heredity NSES p.185
Biological evolution NSES p.185

Referenced Common Misconceptions:
“Pupils appear to understand little of the nature or function of genes and chromosomes, not appreciating that there is a chemical basis to inheritance.” (Driver, et al., pg 52).
Essential Questions:
What is the difference between genotype and phenotype?
How is a lab notebook set up?

Student Behavioral Objectives:
- Students will distinguish between genotype and phenotype.
- Students will graph the class results in an easy to understand graph.
- This should be the first lab that goes into the student’s lab notebook so that they can start setting up their notebook.

Description of the lab:
Students conduct an inventory of traits that are similar and different in the classroom. They make histograms of the data to help them understand the relationship between genotype and phenotype.

Inquiry: 3. Work in groups of 2 to 3 students.

Materials:
Handout copies (from Activity)
A clean white board to put the data on. Please read the protocol for a complete list of materials.

Safety Considerations: None

Assessments:
Pre-assessment: A pre-test will be given to assess students’ current knowledge on making graphs and differences between phenotypes and genotypes.

Participation: Question and answer session,
Performance base: during and after the lesson.
Graphs to be turned in for grading. Lab notebook should follow specified format.

Real world connections: Examples of genetic variations in nature and how they may help a population of specie’s survive. Example could include the pepper moth.

Unit 3: Lesson 3: 3rd week: Constructing a Paper Helix (pgs 144 – 148 in Recombinant DNA and Biotechnology Book)

Time Planned for activities: one class period 50 minutes

Student Prior Knowledge:
What DNA is, but not entirely necessary.
DNA is the molecule that stores genetic information.

Knowledge Gained from Lesson:
- What a DNA strand looks like.
- What complementary base pairs are and what nucleotide pairs with what.
- Genetic variability is due to a variety of factors.
Concepts to be covered after this lesson:
- The students will be working with genetic variability all year.
- The students will be leading up to natural selection and Biological Evolution.

Arizona Standards:
Science Standards
- Strand 4: Concept 2: PO1
- Concept 4: PO1

NSES:
Life Science
- The molecular basis of heredity NSES p.185
- Biological evolution NSES p.185

Referenced Common Misconceptions:
“Though students are usually familiar with the base pairs, they often do not understand the antiparallel orientation of the two DNA strands and usually have not thought about the fact that 5’ and 3’ ends of the strands are different…” (Kreuzer, pg. 118).

Essential Questions:
- What is the structure of DNA?
- How does meiosis and mutations contribute to genetic variability?

Student Behavioral Objectives:
- Students will visualize a double helix strand of DNA and make a paper model of DNA.
- Students will identify that adenine pairs with thymine and that cytosine pairs with guanine.
- Students will give examples of how genetic variability can be due to meiosis, mutation and recombination of genes.

Description of lab:
Students use paper to make an easy to assemble DNA helix. The model is used to explain the anti-parallel orientation of the DNA molecule. (Kreuzer, pg. 144).

Modeling Inquiry: 3
Work in groups of 2 to 3 students.

Materials:
Copies of the parts of DNA, template found in Activity,
Scissors, tape or glue, please see the protocol for a complete list of materials.

Safety Considerations:
Paper cuts, and running with scissors. I suggest blunted tips scissors regardless of age due to students talking with their hands and accidentally stabbing each other.
Assessments:

Pre-assessment: Check their knowledge about DNA molecules.

Participation:
Performance based: How their DNA model looks.

Content knowledge: What the model represents.

Real world connections:
Show them pictures of real DNA molecules. Tell them that we will be working with real DNA in the future. DNA is found in all living organisms. Slight differences in DNA are the reasons for phenotypic diversity in the classroom.

Unit 3: Lesson 4: 4th week: The Size of the Genome Activity (pgs 179 – 181 in Recombinant DNA and Biotechnology Book)

Time Planned for activities: one class period 50 minutes

Student Prior Knowledge:
- Where the DNA is located in a cell.
- The difference between prokaryotes and eukaryotes.

Knowledge Gained from Lesson:
- How big DNA really is in comparison to the nucleus.
- How the spiral helix coils to allow the DNA to fit in such a small area.

Concepts to be covered after this lesson:
- The students will be going into further depth in their study of the cell.
- They will be studying mitosis and meiosis and how meiosis leads to greater diversity than binary fission.
- They will be studying natural selection in depth.

Arizona Standards:
Science Standards
Strand 4: Concept 1: PO1
Concept 2: PO1

NSES:
Life Science
The cell NSES p.184
The molecular basis of heredity NSES p.185

Referenced Common Misconceptions:
“Though students re usually familiar with the base pairs, they often do not understand the antiparallel orientations of the DNA strands and usually have not thought about the fact that 5’ and 3’ ends of the strands are different….”(Kreuzer, pg.118).

Essential Questions:
How do prokaryotic and eukaryotic cells differ?
Why is the DNA molecule helical?
Student Behavioral Objectives:
- Student describes part of the reason for the double helix shape of the DNA molecule.
- The student will compare and contrast prokaryotes and eukaryotes in terms of shape and cellular components.

Description of the lab:
This activity uses models to demonstrate the relative sizes if the E.coli cell, its chromosomes, a typical plasmid, and a gene.

Modeling Inquiry: 4
Work in groups of 2 to 3 students.

Materials:
Gel capsules, yarn and thread(different colors of both), scissors, tap, please read the protocol for a complete list of materials.

Safety Considerations:
Make sure that no one wraps the thread around someone’s neck or that they are blocking a walkway.

Assessments:
- Pre-assessment: Their knowledge about DNA molecules.
- Participation:
  - Performance based: How they get their DNA into the capsule.
- Content knowledge: What the model represents and how relates to real life.

Real world connections:
- The real size of the human genome.
- How the DNA is comparable in many different organisms.

Unit 3: Lesson 5: 5th week: Gel Electrophoresis of Dyes Lab (BioRad Kit)

Time Planned for activities: two class periods 50 minutes each. (1 class period to practice with micropipette and pouring gels, the other to run the dyes)

Student Prior Knowledge:
- What gel electrophoresis is and how it is used as a tool.
- How to write up labs in their lab notebook.

Knowledge Gained from Lesson:
- How to set up a gel electrophoresis and interpret the results.
- To understand that molecules are different sizes and have different charges.

Concepts to be covered after this lesson:
- DNA molecules are negatively charged and therefore will migrate to the positive charge of the gel electrophoresis plate.
- The next step is to run actual DNA in the gel electrophoresis.
Arizona Standards:

Science Standards
- Strand 1: Concept 2: PO1- PO5
- Concept 3: PO1 & PO2
- Concept 4: PO1-PO4
- Strand 4: Concept 4: PO5 & PO6

NSSS
- Science as Inquiry NSES p.175
- Life Science
  - The cell NSES p.184
  - Biological evolution NSES p.185

Referenced Common Misconceptions:
Students have some understanding that characteristics are determined by a particular genetic entity which carries information translatable by the cell” (Benchmarks, p. 341). “Though students are usually familiar with the base pairs, they often do not understand the antiparallel orientation of the two DNA strands and usually have not thought about the fact that 5’ and 3’ ends of the strands are different…” (Kreuzer, pg. 118).

Essential Questions:
What is gel electrophoresis?
How does gel electrophoresis work?

Student Behavioral Objectives:
- Students will set up a gel electrophoresis, run a gel electrophoresis, and interpret the results.
- Students will explain that molecules are different sizes and how that causes the dyes to separate on the gel.
- Students will describe the polarity of molecules.

Description of the lab:
Students practice lab skills needed to experiment with DNA using dyes. This simple lab is a good indicator of lab skills before students experiment with more expensive DNA and restriction enzymes.

Inquiry: 5
Level 2. Students are given a procedure, but skill level and interpretation of the results is student oriented

Materials:
Gel electrophoresis equipment, agar, dyes, the BioRad kit, please read the protocol for a complete list of materials.

Safety Considerations:
Students should wear gloves, goggles, and protective wear for their clothing.

Assessments:
- Pre-assessment: Check their knowledge about gel electrophoresis and how it separates molecules.
- Participation: Performance based: How their gel looks at the end of the experiment. How complete their lab notebooks are.
Content knowledge:
What exactly does a gel electrophoresis do and what are the many applications?

Real world connections:
How gels are used in forensics, agricultural applications, and other biotechnology applications.

Unit 3: Lesson 6: 6th week: DNA Extraction from Fruits (with comparisons of different DNA’s from different organisms). Unit 5, last activity: Relating Genetics to Everyday Life book

Time Planned for activities: one class period 50 minutes

Student Prior Knowledge:
- What a DNA molecule is, where it is located, and what does it do for the organism.
- How to write up labs in their lab notebook.

Knowledge Gained from Lesson:
- DNA pretty much looks the same from every sample.
- Why is DNA the same? The student should be able to explain the similarities between organisms and their DNA and what causes the differences between organisms.
- DNA extraction is simple.
- DNA jewelry is cool.

Concepts to be covered after this lesson:
- What are the different techniques that are used after DNA extraction to further our knowledge about diseases, forensics, agricultural applications, etc?
- DNA analysis of organism relatedness.

Arizona Standards:
Science Standards
Strand 1: Concept 2: PO1-PO5
   Concept 4: PO1-PO4
Strand 2: Concept 1: PO1
   Concept 2: PO3
Strand 4: Concept 2: PO2
   Concept 4: PO3

NSES:
Science as Inquiry NSES p.175
Life Science
   The molecular basis of heredity NSES p.185
   Biological evolution NSES p.185

History and Nature of Science
   Science as a human endeavor NSES p.200
   Nature of scientific knowledge NSES p.201
Referenced Common Misconceptions:
Students have difficulty thinking of DNA as a molecule. Students tend to think that molecules of protein are larger than the size of a cell. (Driver, et al. pg.25)

Essential Questions:
How does DNA vary among organisms?

Student Behavioral Objectives:
- The students will identify that DNA pretty much looks the same for every sample (organism).
- The students will compare and contrast the number of chromosomes in an organism
- The students will predict if the number of chromosomes makes an organism complex or not.
- The students will discover that the lab techniques are easy and can lead to more complex, but interesting labs.

Description of the lab:
Students will isolate DNA from various fruits. They will explain how each chemical is involved in the DNA extraction.

Inquiry:
This is a non-inquiry structured activity with predetermined procedures and outcomes.

Materials:
Different types of fruits, microscopes, DNA jewelry containers, read protocol for complete list of materials.

Safety Considerations:
Students should wear goggles, gloves, and clothing protection. Students should not be sensitive to fruit being mashed up.

Assessments:
Pre-assessment: What do students predict that the DNA will look like? Do they think that the different organisms DNA will look different?

Participation:
Performance based: Did the group obtain DNA? Did they take the lab one step further and look at it under the different types of microscopes? They will also be assessed on the completeness of their lab notebook.

Content knowledge:
What does this lab tell the student about DNA, the appearance of DNA, and how DNA differs among organisms?

Real world connections:
Have students do research on a topic that interests them and how DNA sequencing has furthered research in that area.
Unit 3: Lesson 7: 7th week: DNA Fingerprinting Lab (BioRad kit)

Time Planned for activities: two class periods 50 minutes each

Student Prior Knowledge:
- How to set up and run a gel electrophoresis.
- That DNA molecules are negatively charged and of different sizes.
- Why larger molecules won’t travel as far as the smaller molecules.
- How to write up labs in their lab notebook.

Knowledge Gained from Lesson:
- Using evidence to support how their crime story was solved using biotechnology.
- How this technology can be used in a classification system.

Concepts to be covered after this lesson:
- The different types of classification systems.
- Students will decide the pros and cons of each system.

Arizona Standards:
Science Standards
- Strand 4: Concept 4: PO6
- Strand 1: Concept 2: PO1-PO4
  - Concept 3: PO4
  - Concept 4: PO3 & PO4
- Strand 2: Concept 1: PO2 & PO3

NSES:
- Science as Inquiry NSES p.175
- Life Science
  - Biological evolution NSES p.185
- History and Nature of Science
  - Science as a human endeavor NSES p.200

Referenced Common Misconceptions:
Students have some understanding that characteristics are determined by a particular genetic entity which carries information translatable by the cell.” (Benchmarks p. 341) “In general, students recognize the idea of species as a basis for classifying organisms, but few students will refer to the genetic basis of species.” NSES p.181

Essential Questions:
How does biotechnology support the patterns in the fossil record?

Student Behavioral Objectives:
- The students will follow lab protocols. The students will describe practical real world applications for this type of technology.
- The students will explain how this technology could be used as part of a classification system by analyzing the degree of relatedness among species.
Description of lab:
This lab is used to determine who committed a crime by linking DNA evidence from a “crime scene” to DNA from several suspects. This lab is a spin-off from popular shows like CSI, which involves forensic testing. Students familiar with DNA, the use of restriction enzymes, and gel electrophoresis should be able to develop procedures to test and analyze the DNA provided. One 50- minute class period is required; some gels can be stained overnight and viewed the next day.

Inquiry: 6
Level 2 inquiry if students use a pre-determined scenario and procedures. Level 3 inquiry if students develop their own scenario and procedures.

Materials:
Gel electrophoresis equipment, BioRad kit, DNA samples, agar, please read the protocol for a complete list of materials.

Safety Considerations:
Students should wear goggles, gloves, and clothing protection.

Assessments:

Pre-assessment: Assess how well the students understand the concept of how a gel electrophoresis works and what data it will produce.

Participation:
Performance based: Can the student follow the protocol? Is the lab notebook complete? How does the gel look and can the student get data from the gel?

Content knowledge:
The student should be able to explain different types of classification systems, including DNA analysis.

Real world connections:
Explain how DNA is used in Forensics, but they already know – they watch CSI and NCIS just like the rest of us. To emphasize the connection to forensics, ask students to create crime science stories before they run the DNA samples.

Unit 3: Lesson 8: 8th week: Microarray Lab
BioRad Kit’s Instructions

Time Planned for activities: two class periods 50 minutes each

Student Prior Knowledge:
- General basic knowledge of how microarrays work.
- What a SNP is.
- How to write up labs in their lab notebook.

Knowledge Gained from Lesson:
- How microarrays are used in disease detection.
- How microarrays are used in gene detection in conjunction with family pedigrees as in the Huntington’s lab activity.
Concepts to be covered after this lesson:
- More gene detection lab activities such as the Huntington’s lab as well as the BioRad’s Breast Cancer Detection Lab kit.
- The students will be doing their own literature research into a specific disease and the biotechnologies that are currently being used with that disease.

Arizona Standards:
- Science Standards
  - Strand 4: Concept 4: PO2 & PO3
  - Strand 1: Concept 1: PO1-PO4
    - Concept 2: PO2, PO2 & PO5
    - Concept 3: PO1, PO2 & PO4
    - Concept 4: PO1-PO4
  - Strand 2: Concept 1: PO2-PO4
    - Concept 2: PO2-PO4

NSES:
- Science as Inquiry NSES p.175
- Life Science
- Biological evolution NSES p.185

History and Nature of Science
- Science as a human endeavor NSES p.200
- Nature of scientific knowledge NSES p.201

Referenced Common Misconceptions:
Students have some understanding that characteristics are determined by a particular genetic entity which carries information translatable by the cell” (Benchmarks, p.341). “In general students recognize the idea of species as a basis for classifying organisms, but few students will refer to the genetic basis of species” (NSES, p.181).

Essential Questions:
How does biotechnology aid in the diagnosis of diseases?

Student Behavioral Objectives:
- The students will follow lab protocols.
- The students will explain how this technology could be used to help in the diagnosis of disease as well how this technology could be used in other health related issues.

Description of the lab:
This activity uses DNA technology to examine the relationship between genes and over/under amplification of proteins that may lead to identifying various diseases such as cancer.

Inquiry 6: Students work in groups and follow a strict protocol. Students then reflect on how the procedure could be applied to other areas and used to identify various health-related illnesses. Students communicate their explanations using the evidence they have collected to support their explanations.
Materials:
Slides already pre-setup, solutions made up, please see protocol for complete set of materials.

Safety Considerations:
Students should wear goggles, gloves, and clothing protection.

Assessments:

Pre-assessment: Assess how well the students can describe the concept of how microarrays work.

Participation:
Performance based: Can the student follow the protocol? Is the lab notebook complete? How does the completed microarray look? Can the student explain exactly what the results from the microarray mean?

Content knowledge: The student should be able to predict how a pedigree is used to demonstrate the heredity of a disease and how a microarray would help in the diagnosis of the disease.

Real world connections:
- The students will get the chance to find out what diseases are actually being diagnosed at this time with this technology.
- The students will find out what diseases are currently being studied this way at T-Gen (based on our course this summer.)

Unit 3: Lesson 9: Week 9: Pre-Field Trip Lesson Plan Classification Systems: Classifying Foam Shapes (colored cut-out foam shapes)
Day 1

Time Planned for activities: one 45 minute class

Student Prior Knowledge:
- The difference between genotype and phenotype.

Knowledge Gained from Lesson:
- That each group classified their shapes based on different characteristics or groupings than the other groups.
- That scientists use standardized systems of classification, but even those can be unique: i.e., cladograms.
- What shared derived characteristics are and how they are used to create cladograms.
- The difference between a phylogenetic tree and a cladogram.

Concepts to be covered after this lesson:
- That anatomically, some dinosaurs and birds seem to be very closely related.
- That dinosaurs are most likely more closely related to birds than reptiles as originally thought.
- Other systems of classification.

Arizona Standards:
Science Standards
- Strand 1: Concept 4: PO3 & PO4
- Strand 4: Concept 4: PO6
NSES:
Science as Inquiry  NSES p.175
Life Science
Biological evolution NSES p.185

Referenced Common Misconceptions:
“…children of all ages focused on more obvious features such as number of limbs or habitat rather than on more fundamental differences such as physiology, when classifying living things” (Driver, et al, pags 24-25).

Essential Questions:
What is the difference between a phylogenetic tree and a cladogram?

Student Objectives:
- The students will classify their foam shapes according to a system that they can replicate and explain clearly.
- The students will describe the difference between a phylogenetic tree and a cladogram.

Description of the lab:
Students will practice the science of classification using foam shapes. Students will use phylogenetic trees and cladograms as models for their explanation of their classification systems.

Inquiry: Q&A
Students are asked to explore and explain their own systems of classification. Students are using models to strengthen their explanations and abilities to communicate their ideas to their peers for review. This activity focuses on the use of evidence to support student explanations.

Materials and Safety Considerations:
Foam shapes can be purchased at any store that has arts and crafts supplies.
No safety considerations other than the students should clean up after themselves.

Assessments:
Pre-assessment: The students will be asked to write a bellwork assignment explaining the difference between Linnaeus’ system of classification, a phylogenetic tree, and a cladogram.
Participation:
Performance based: The student will be actively involved in classifying his/her foam shapes with his/her group. The student will explain to the teacher how the group classified the foam shapes.

Post-Lesson Assessment
The day after this lesson, the students will be given the same bellwork as today to compare their answers and to make sure that they understood the underlying concept of the lesson.

Real world connections:
- People classify things in their everyday lives all of the time.
- Scientists use classification systems to understand the degree of relatedness among organisms.
- Jurassic Park seemed to bring the idea into the main stream of non-scientists that dinosaurs are related to birds.
Week 9: Pre-Field Trip Lesson Plan: Preparation for Field Trip: Cladograms, field observations, writing in lab notebooks

Day 2

Time Planned for activities: one 45 minute class

Student Prior Knowledge:
- The difference between genotype and phenotype.
- The students should have read this chapter in advance of this activity.
- The difference between a phylogenetic tree and a cladogram.
- What shared derived characteristics are and how they are used to create cladograms.
- How to write in their lab notebooks.

Knowledge Gained from Lesson:
- The ability to design a cladogram based on shared derived characteristics.
- That anatomically, some dinosaurs and birds seem to be very closely related.
- That dinosaurs are more likely related to birds than reptiles as originally thought.
- Other systems of classification include genetic and protein based classification systems.

Concepts to be covered after this lesson:
- What is expected of the students during the field trip to the Arizona Museum of Natural History.
- What did the students learn specifically about feathered dinosaurs and the origin of flight?
- Students’ completed cladograms.

Arizona Standards:
Science Standards
Strand 1: Concept 4: PO3 & PO4
Strand 4: Concept 4: PO5 & PO6

NSES
Science as Inquiry NSES p.175
Life Science
Biological evolution NSES p.185

Referenced Common Misconceptions:
There are no ways to date fossils. Personal experience.

Essential Questions:
Are dinosaurs more related to birds than reptiles?

Behavioral Objectives:
Increase awareness of field trip expectations.

Description of the lab:
Students will practice developing classification schemes using fossil evidence to support their explanations for the way they classified their organisms.
Inquiry
Students explore and explain their own systems of classification. Students are using models to strengthen their explanations and abilities to communicate their ideas to their peers for reviews. This activity focuses on the use of evidence to support student explanations.

Materials and Safety Considerations:
Pictures of fossilized organisms, a minimum of six organisms per group of 4 students working together. No safety issues other than students should be on task.

Assessments: None

Real world connections:
✓ This is practice for what the students will be doing on the Arizona Museum of History field trip.

Unit 3: Lesson 10: Week 9: Pre-Field Trip Lesson Plan: Preparation for Field Trip: PowerPoint of Field Trip and Worksheet instructions

Day 3

Time Planned for activities: one 45 minute class

Student Prior Knowledge:
✓ The difference between genotype and phenotype.
✓ The students should have read this chapter in advance of this activity.
✓ The difference between a phylogenetic tree and a cladogram.
✓ What shared derived characteristics are and how they are used to create cladograms.
✓ How to write in their lab notebooks.
✓ The ability to design a cladogram based on shared derived characteristics.
✓ That anatomically, some dinosaurs and birds seem to be very closely related.
✓ That dinosaurs are most likely more closely related to birds than reptiles as originally thought.
✓ Other systems of classification include genetic and protein based classification systems.

Knowledge Gained from Lesson:
✓ What is expected of the students during the field trip to the Arizona Museum of Natural History.
✓ How to fill out the worksheet that is to be completed at the museum.

Concepts to be covered after this lesson:
✓ What did the students learn specifically about feathered dinosaurs and the origin of flight?
✓ Students’ completed cladograms.

Arizona Standards:
Science Standards
Strand 1: Concept 4: PO3 & PO4
Strand 4: Concept 4: PO5 & PO6

NSES
Science as Inquiry NSES p.175
Life Science
Biological evolution NSES p.185
Referenced Common Misconceptions:
None

Essential Questions:
What is acceptable behavior at the museum?

Student Objectives:
- The students will explain how to fill out the worksheet when they are at the museum.
- The students will describe exactly why we are taking a field trip to the museum.
- The students will explain what acceptable and unacceptable behavior is at the museum and they are to remain with their adult sponsor at all times.

Description of the lab:
Students are learning proper behavior and what do to when they get to the museum. This is the time to ask questions to make sure students know exactly what is expected of them in terms of what to do and how to act while visiting the museum.

Inquiry
Teacher directed and explained.

Material and Safety Considerations:
PowerPoint and sample field trip worksheet, no safety considerations except for during the field trip itself.

Assessments
Pre-assessment:
Q & A: what is acceptable behavior on field trips.
Q & A: Why are we going to the museum?

Participation:
Performance based: Modeling, students will be going over the worksheet that they will be filling out during the field trip. Students will be asking questions as to the nature of the field trip.

Post-Lesson Assessment
The students will be able to answer questions regarding how to fill out the field trip worksheet. The students will be able to answers questions as to when and where to meet the bus. The students will be able to answer questions as to the purpose of the field trip. The students will be able to answer questions regarding appropriate behavior during the field trip.

Real world connections:
- Real world connections to the actual fossils that we have been studying in our book.

9th week: Field Trip Lesson Plan: The Arizona Museum of Natural History Field Trip
4th Day

Time Planned for activities: 1 day
Student Prior Knowledge:
- How dinosaur, reptile, and bird bones and other characteristics are similar anatomically.
- What shared derived characteristics are and how they are used to create cladograms.
- How to write up labs in their lab notebook.

Knowledge Gained from Lesson:
- Using observations as evidence to support how the dinosaur, reptile, and bird anatomy are very similar.
- How these anatomical characteristics could be shared derived characteristics on a cladogram.
- How to make their own cladogram of dinosaurs, reptiles, and birds based on what morphological traits the students deem important to their cladogram.

Concepts to be covered after this lesson:
- How to refine the cladograms that they made with additional information researched.
- Will do the FISH protein lab so the students can determine the degree of relatedness among different fish species.
- Students will make cladograms before and after the FISH protein lab using the data they collect during the lab.
- Students will attempt to extract DNA from bird bones.

Arizona Standards:
Science Standards
- Strand 4: Concept 4: PO1- PO6
- Strand 1: Concept 1: PO1
- Concept 4: PO3 & PO4
- Strand 2: Concept 2: PO2- PO4

NSES
Science as Inquiry NSES p.175
Life Science
- Biological evolution NSES p.185
History and Nature of Science
- Nature of scientific knowledge NSES p.201

Referenced Common Misconceptions:
There are no ways to date fossils. Personal experience.

Essential Questions:
Are dinosaurs more related to birds than reptiles?

Student Objectives:
- The student will identify anatomical differences and similarities between dinosaur, reptile, and bird bones.
- The student will design a cladogram of six dinosaurs, six reptiles, and six birds based upon the observations made at the Natural History Museum during the field trip.
Description of the lab:
Students are classifying organisms in the museum using relatedness and differences between various organisms. Students produce a cladogram explaining how and why they have classified organisms and communicate those claims to the teacher as well as to the class and be able to defend why they did what they did.

Inquiry
By having students use the evidence they have collected to support a claim or explanation, students are conducting an open inquiry activity. Students must defend the choices they have made and explain their reasoning.

Material and Safety Considerations:
Materials: The students need their field trip worksheet, paper and pencils, any personal items deemed necessary by the student. Cell phones must be turned on vibrate and put in backpacks during the museum tour.

Safety First. Students should be in their assigned groups at all times with their adult supervisor. The bus should have a first-aid backpack. The teacher should have all of the personal contact numbers and special health considerations for all students with her/him.

Assessments:
Pre-assessment: The student should attempt to make a cladogram of six dinosaurs, six reptiles, and six birds based on their prior knowledge of those animals down to the museum.

Participation: The students will have a completed field trip worksheet by the end of the field trip so that they can complete their cladograms. The students should tour as many other exhibits as possible with their supervisor in order to gain more information to complete their sheet with as well as obtain information on evolution to discuss back in the classroom.

Post-Assessment: The student should have a cladogram of at least six dinosaurs, six reptiles, and six birds to turn in based on morphological characteristics that the student deems important. The students will be able to explain to the teacher why they picked the shared derived characteristics that they did to construct the cladogram.

Real world connections:
How scientists use the available research to determine the degree of relatedness among animals and how these cladograms are able to change due to new information and new techniques.

Unit 3: Lesson 11: 9th week: Post Field Trip
Lesson Plan: Field Trip Debriefing Activity
5th Day

Time Planned for activities: one 45 minute class

Student Prior Knowledge:
- How dinosaur, reptile, and bird bones and other characteristics are similar anatomically.
- What shared derived characteristics are and how they are used to create cladograms.
- How to write up labs in their lab notebook.
Seeing with their own eyes how the dinosaur, reptile, and bird anatomy are very similar.

How these anatomical characteristics could be shared derived characteristics on a cladogram.

How to make their own cladogram of dinosaurs, reptiles, and birds based on what morphological traits the student deems important to his/her cladogram.

**Knowledge Gained from Lesson:**
- How to refine the cladograms that they made with additional information researched.
- Debrief from field trip: What did they learn? What went wrong? What went right? What could be changed to make the trip better?

**Concepts to be covered after this lesson:**
- Will do the FISH protein lab so the students can determine the degree of relatedness among different fish species.
- Students will make cladograms before and after the FISH protein lab using the data they collect during the lab.
- Students will attempt to extract DNA from bird bones.

**Arizona Standards:**

**Science Standards**
- Strand 1: Concept 1: PO1
- Concept 4: PO3 & PO4
- Strand 2: Concept 2: PO2- PO4
- Strand 4: Concept 4: PO1- PO6

**NSES**
- Science as Inquiry [NSES p.175](#)
- Life Science
  - Biological evolution [NSES p.185](#)
- History and Nature of Science
  - Nature of scientific knowledge [NSES p.201](#)

**Referenced Common Misconceptions:**

“…it suggests that students may not understand before they abandon their beliefs about knowledge being either right or wrong that scientists can legitimately hold different explanations for the same set of observations” (Benchmarks, pg. 333).

**Essential Questions:**
Are dinosaurs more related to birds than reptiles?

**Student Objectives:**
- The students will design a cladogram of six dinosaurs, six reptiles, and six birds based upon the observations made at the Natural History Museum during the field trip.
- The students will share their cladograms with the class.

**Description of the lab:**
Students share their cladograms and defend their choices with the class.
**Inquiry:** students justify and defend the ways in which they classified organisms, thus practicing their communication skills. This activity is the culmination of the open-inquiry activity that previously occurred.

**Material and Safety Considerations:**
None

**Assessments:**

**Pre-assessment:** The student will have a completed filed trip worksheet by the end of the field trip so that they can complete their cladograms.

**Participation:** Performance Based: The student should have a cladogram of at least six dinosaurs, six reptiles, and six birds based on morphological characteristics that the student deems important.

**Post-lesson Q&A:** Closure done by the students: what did they learn? Do they feel comfortable with cladograms? How would they change their cladograms based on additional research? What would they change about the worksheet to make it more user friendly?

**Real world connections:**
How scientists use the available research to determine the degree of relatedness among animals and how these cladograms are always changing due to new information and new techniques.

Field Trip Worksheets below: This should be double-sided and stapled. 1 per student, with extras for those students that lose theirs.
<table>
<thead>
<tr>
<th>Name of Animal</th>
<th>Aquatic or Land-dwelling</th>
<th>Walked on four legs or Walked on two legs</th>
<th>Had wings or no wings</th>
<th>Teeth or no teeth</th>
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<th>Distinguishing feature</th>
<th>Carnivore or herbivore or omnivore</th>
<th>Notes</th>
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Additional Notes

Sketches

Group Supervisor Sign Here When Completed: _________________________________
Performance Tasks (summarized with criteria for evaluation)

**Lab:** Students will follow the protocol as given to them or described by the teacher. Students will keep a lab notebook of all of the labs they do during the year according to the lab notebook set-up worksheet given at the beginning of the school year.

**Scoring Rubric for labs and lab notebook:**

- **90 – 100 points A**
  The lab notebook is neat and orderly, the drawings and graphs are drawn neat, labeled correctly, and organized in the notebook. All components of the lab notebook are in the notebook. The student follows protocols in the labs, participates, takes the labs seriously, helps others when they need help, asks appropriate questions of the teacher when the student has difficulties.

- **80 – 89 points B**
  The lab notebook is neat and orderly, the drawings and graphs are for the most part drawn neat, labeled correctly, and organized in the notebook. Most of the components of the lab notebook are in the notebook. The student follows protocols in the labs, participates, takes the labs seriously, asks appropriate questions of the teacher when the student has difficulties.

- **70 - 79 points C**
  The lab notebook is fairly orderly and the drawings and graphs are for the most part drawn neat, labeled correctly, and somewhat organized in the notebook. Some of the components of the lab notebook are in the notebook. The student follows protocols in the labs, participates, and takes the labs seriously.

- **60 – 69 points D**
  The lab notebook is inconsistent, doesn’t have many of the components required in the lab notebook. The drawings and graphs are not labeled and haphazard. The student doesn’t follow all of the protocols in the labs, participates on an inconsistent level, and does not take the labs seriously.

- **< 59 points F**
  If the lab notebook is even turned in, it has few components that are required. The student usually doesn’t participate in the lab at all. The graphs and drawings are inconsistent and have obviously been drawn in a hurry and with no attention to detail.

**Other Evidence – Describe assessments other than performance tasks.**

The students will be evaluated by the teacher during each lab as to the progress they make throughout the year as well as the above standards. The teacher and the student will have opportunities for informal question and answer sessions during the lab to ascertain that the student has a complete comprehension of why they are doing the lab and what concepts they should be learning.
Quizzes, Tests, Prompts, and Work Samples (summarized)

There will be a unit test at the end of each unit studied. The unit tests will include: multiple choice questions, true and false questions, fill in the blank questions, labeling pre-drawn pictures, short answer questions, problem solving, and one critical thinking essay.

Unprompted Evidence (observations/dialogues)

The student and teacher will be conversing on a regular basis about his/her progress on the ten unit teacher expectations of the student. This informal/formal dialogue will keep both the student and the teacher informed of the student’s progress.

At the end of each day, the teacher will orally test students over what they learned that day as well as previous days in the unit. In addition, the students will conduct the lesson closure which can be stating or writing what they learned.

Student Self-Assessment

This will be addressed the same as described under unprompted evidence. This gives the student a chance to clarify any misunderstandings they may have about the material.

VI. DIRECTIONS TO TEACHERS TO ACCOMPANY UNIT

What information will teachers need to be successful teaching your unit?

To be successful in teaching this unit the teacher must come to the unit with an open mind. This unit is certainly not designed to change students’ personal beliefs in any way. However, the student must understand that they have to learn the theory of evolution in order to be successful in the class as well as on the science AIMS test. It is, however, designed to get the students to think for themselves, to research ideas of interest, and to formulate an explanation for observed phenomena. This unit is designed not only to teach the theory of evolution in an in-depth manner, but also to get the students to look beyond what is in the textbook and to think outside the box.

Misconception alerts:

The main ones I hear from my students are: the fossil record is wrong, there are no ways to date fossils, the Earth was made in 6 24 hour days, the Earth is only a few thousand years old, evolution means that humans evolved from monkeys, Darwin was the devil, Darwin invented evolution, natural selection is a thing that animals do to themselves, and so on.

The students also think that animals choose to make adaptations to themselves instead of genetic variations happening to the animal and it’s offspring. The students have difficulties understanding that the individual animal is quite unimportant in biological evolution and that the species is the crux of the matter. I think that this stems from humans being rather egocentric and individualistic which precludes them, in general, of thinking of species as a whole instead of individuals.

In the book Making Sense of Secondary Science, the authors give the following misconception for biotechnology: “bacteria could be useful when dead, for making medicines or vaccines, but there was little evidence of notions about the technological potential of living microbes.” Pg. 57. I am sure I will run into more misconceptions on biotechnology as I get going with the students.
XI. References:

Books:


Activities:
1) Cube activity (pgs. 66-73) Teaching about evolution and the nature of science
2) Alike but not the same (activity 1) Relating genetics to everyday life. [Alike but Not the Same](http://science.education.nih.gov/supplements/nih1/genetic/activities/activity1.htm)
3) Constructing a paper helix (pgs. 144-150) Recombinant DNA and biotechnology
4) The size of genome activity (pgs. 176-181) Recombinant DNA and biotechnology
5) Gel Electrophoresis of Dyes Lab Bio-Rad Kit:
6) DNA extraction from fruits (Unit 5 last activity) Relating genetics to everyday life
7) DNA fingerprinting lab Bio-Rad Kit: ?
8) Microarray Lab Bio-Rad Kit: ?
9) Classification Systems: Classifying foam shapes: ?