

EVOLUTION

Introduction: The Development and Alignment of the Concepts Related to Evolution in the Science TEKS

To attain the Biology TEKS concerned with evolutionary theory, it is necessary that students learn certain prerequisite concepts as identified in the Science K-8 TEKS. The flow and alignment of these concepts are depicted in this strand map and briefly described in this narrative.

Strand Map: Themes (The strand map was prepared on Inspiration software and does not accompany this document)

The strand map organizes the evolution-related Science TEKS using the following 5 themes:

- classification
- characteristics, adaptations, and survival
- survival, variation, and change
- past events
- methods of science.

K-2

In grades K-2, students learn that organisms have characteristics that help them to meet their basic needs so as to survive and reproduce. For example, food is a basic need for birds. The beaks of birds are adapted to get food in different ways. Thus, the beak of a hummingbird is much different than that of a hawk, sparrow, duck, or pelican. This concept continues to be emphasized in the TEKS designated for later grades and biology.

Grade 3

In grade 3, students are introduced to the concept that characteristics, or adaptations, of plants and animals help them live and reproduce in their environment. Thus, the wings of birds are adaptations for flight and the fins of a fish are adaptations for swimming.

Students also learn that competition for resources exists among organisms with similar needs and, as a result, some organisms cannot survive and reproduce. For example, both trees and grass need sunlight to grow and reproduce. Some kinds of grass planted in parks and yards cannot grow when trees in these areas grow so large that the grass cannot get enough sunlight to survive and reproduce. As the grass dies, insects and other organisms living in the grass also are affected and may not survive.

Grade 4

In grade 4, students learn that fossils provide a record of organisms that lived in the past and can be used to compare the kinds of species that lived in the past with those of today. Fossils show that dinosaurs lived in the past, but have not lived on earth for a long period

of time. Also, fossils provide evidence of how a certain species has changed. For example, both horses and elephants were much smaller in the past.

Adaptations and their relationship to the survival and reproduction of organisms continue to be emphasized. Also, the adaptations of different species are compared. Many animals must move to get food to live and reproduce. The adaptations that these animals use for movement are quite varied and include the fins of fish, the wings of birds, the jumping legs of grasshoppers, and the sticky feet of houseflies.

A study of fossils and other data is used to help students answer the question “what happened before” in the context of the history of the natural world. For example, the extinction of the dinosaurs continues to evoke the question “what happened?”

The concept that past events affect present and future events is introduced. In simple terms, this means changes or events that occur at a given time may continue to impact future events. For example, the birds that live in a forest will be different than those living in the same area after a fire. The plants and other animals will be different. As a result, the interactions between animals present in the area will be different before and after a fire. Long term examples also can be provided. For a 4th grade student, long term may be quite recent in terms of the long history of the natural world and local examples may have to be given. Shopping centers and other developments have replaced grasslands, desert land, and forests. Organisms living in these areas are now different, as are the interactions that occur among the organisms living in these areas now. Because of the changes in the environments of these areas, the organisms living there successfully have different adaptations than those living there earlier.

Grade 5

Grade 5 TEKS emphasize adaptations and their importance in the survival of organisms in the context of an organism’s niche and ecosystem. Thus, some adaptations that increase the chance of survival for a whale would be different than those of a hawk because of the differences in the niche they occupy.

Adaptations of different organisms also are compared. Seeds of plants have different adaptations that help in their distribution. The seeds of some plants such as apples, peaches, grapes, and strawberries are in sweet fruit that is eaten by different organisms and spread about. Other seeds, such as those of the dandelion and maple tree, have adaptations for flight. Other seeds stick to animals and are spread about as the animals move. Other seeds, like the coconut of palm trees, float in water to other locations.

TEKS at this grade emphasize that conclusions about “what happened before” may be drawn from sources such as sedimentary rock sequences. For example, the type of sediment in a column of soil can provide evidence that volcanoes or floods occurred in an area at an earlier time. Likewise, a rock sequence may show the remains of plants and animals that lived in that area during different periods of time.

The concept that past events affect present and future events continues to be emphasized in grade 5. For example, because of the changes it causes in the environment and the niches occupied by plants and animals, a large volcano in an area will have an immediate affect on organisms living in the area as well as those living there in the future.

Grade 6

In grade 6, the TEKS emphasize that traits of organisms can change over time. The TEKS also emphasize that the instructions for these traits are contained in the genetic material of organisms. As continually emphasized in the TEKS, these traits may effect the ability of the organism to survive and reproduce.

Students in the 6th grade are aware of changes that might occur in the human body. For example, students know that muscles can be enlarged through lifting weights and skills such as playing a piano can be developed. However, the enlarged muscles and the piano-playing skills cannot be passed on to the next generation because the exercise and practice caused no changes in the genetic material of the individuals involved. However, changes made in the genetic material can be passed to the next generation. For example, selective breeding has been used to develop a wide range of diversity in domestic animals and plants. The corn, wheat, cotton, and other crops grown today are much different that grown 200 years ago. Likewise, there is a wide range of diversity in dogs, cats, horses, cows, chickens, and other animals used by humans. Much of this diversity has resulted from selective breeding. In this process, parent plants or animals with desired characteristics are bred in an attempt to develop offspring with a specific set of desired characteristics. This process is sometimes successful and sometimes unsuccessful.

Today, scientists are learning to locate the genetic material in organisms, including that of humans, and identify the traits influenced by this genetic material. As a result, some genes that cause certain diseases in humans have been identified. Other genes that are necessary to produce certain substances needed for a specific activity in the human body have been identified. The presence or absence of such traits can have much influence on whether a specific individual can survive and reproduce. As a result, scientists are interested in finding ways to eliminate or add genetic material in humans as well as in plants and animals that affect characteristics and life processes.

Examples of how the traits of organisms have changed naturally over time are numerous and supported by evidence. Horses and elephants were much smaller in the past. Traits of some organisms that humans have tried to eliminate illustrate and also provide evidence that traits of organisms change over time. For example, when first introduced the insecticide DDT was very effective in killing mosquitoes and flies. However, there is variation within populations of flies and mosquitoes. Some flies and mosquitoes were resistant to DDT and survived to reproduce. Over a long period of time, the frequency of the insects with resistance to DDT increased as the surviving individuals passed on the genetic material responsible for this resistance to their offspring. The frequency of insects that were not resistant to DDT decreased, as they did not survive to reproduce. As a result, DDT became less effective in controlling these insects. The same process is

occurring as certain bacteria that cause human diseases are becoming immune to different antibiotics. This concept continues to be emphasized in grade 7.

Grade 7 and 8

Grade 7 TEKS emphasize that species can change through time. At the same time, the concept that sexual reproduction results in offspring that are diverse is emphasized. Students at this grade level are aware of the differences in characteristics of their brothers and sisters and pups or kittens in a litter. Much of this variation results from the genetic recombination that occurs in sexual reproduction. This diversity can be demonstrated easily by having students note the individuality and distinctiveness found in a sample of common fruits such as apples, lemons, or peanuts. As noted in the narrative for TEKS 6, the differences in traits among individuals in population are important in determining which individuals survive and pass on their genetic material through reproducing. Also, this narrative provides an explanation of how changes in environmental conditions can affect the survival of individuals and a species.

Notice that two clouds are present in the grade 8 segment of the strand map. The concepts stated in these clouds are not in the TEKS but are considered as important in developing student understanding of the overall concept of evolution. One cloud contains the statement that “Biological evolution accounts for the diversity of species developed through gradual processes over many generations.” The narrative explaining how an increasing percentage of existing mosquitoes and flies have become resistant to DDT illustrates how organisms change, or evolve, over time. In the process, there tends to be an increase in the diversity of species that have and continue to exist in the natural world.

The second cloud added states that “Extinction of species is common.” Extinction is the rule in the natural world. More species are extinct than exist today.

TEKS 8.14 emphasizes that natural or human events may contribute to the extinction of species. Most students probably are familiar with the massive extinction of species that is occurring as large areas of tropical rain forests are destroyed. Classical examples of animals driven to extinction by humans include the dodo bird and passenger pigeon. The California condor and the whooping crane are examples of two birds that were nearly extinct but recently have increased in number due to breeding programs and an extensive program to protect them.

The two clouds added to the strand map for grade 8 represent important concepts that are central to evolutionary theory and an understanding of the natural world and its history:

- Biological evolution accounts for the diversity of species developed through gradual processes over many generations.
- Extinction of species is common.

At this stage of study, students should be aware that organisms living today have a history that extends into the past. This awareness and understanding should be connected

to knowledge that there are various theories that have been formulated over a long period of time regarding the origin of the universe.

Biology

The Biology TEKS emphasize the following:

- changes in DNA cause mutations and variations
- the molecular, anatomical, physiological, and embryological evidence of evolution
- the results of natural selection are seen in speciation, the diversity of life, phylogeny, adaptation, and extinction of organisms.

The three clouds added to the strand map for Biology represent important concepts that are central to evolutionary theory:

- Organisms that live on earth today are related by descent from common ancestors.
- The great diversity of organisms is the result of more than 3.5 billions years of evolution.
- There are multiple theories regarding the pace and direction of evolution. One theory indicates that evolution occurs at a relatively constant rate over time whereas another theory indicates that evolution occurs as periods of no change are punctuated periodically with change (Evolutionary change may be gradual or periodic). 5/16/01

Because of the importance of evolutionary theory to our understanding of the natural world and the contributions of many scientists to the development of this theory, Science TEKS 7 and Biology TEKS concerned with the history of biology may be emphasized. Also, a comparison of Lamarckian and Darwinian evolution and questions concerned the pace of evolution could be used in relationship to Biology TEKS 3A.

Biology TEKS 6B emphasizes classification and is included in this strand map inasmuch as modern systems of classification reflect evolutionary relationships. Classification (sorting organisms according to characteristics) was first introduced in TEKS 1.6.

Map Links

As a unifying concept in science, evolutionary theory explains and unites many other concepts. Likewise, evolutionary theory is informed and supported by scientific knowledge from many diverse areas. As a result, the concepts embedded in this strand map are linked to and supported by concepts in other strand maps. Important links exist between Biology TEKS 7 The student knows the theory of biological evolution and the following TEKS:

- Biology TEKS 8: The student knows applications of taxonomy and can identify its limitations.
- Biology TEKS 12: The student knows that interdependence and interactions occur within an ecosystem.

Resources and Research

National Science Education Standards

Evolution is identified as a central and unifying concept in K-12 science by the *National Science Education Standards* (National Research Council, 1996) and as one of the 10 major concepts or ideas required in the Biology TEKS. The seven major concepts concerned with evolution directly in the *National Science Education Standards* are as follows:

- (1) Species evolve over time. Change over time occurs within species due to interaction of environmental and genetic factors.
- (2) Speciation occurs as modification within a single species over time that eventually leads to the inability of once-related species to interbreed. Geologic isolation and reproductive isolation are examples of processes that lead to speciation.
- (3) The diversity of organisms evident today is due to evolution. On the larger ecological scale, the existence of the diverse species on earth, today, is direct result of the evolution of species over time.
- (4) Organisms share some characteristics due to descent from common ancestors. As speciation occurs, new species will share characteristics with other closely related species due to their shared ancestors. This process is also understood as descent with modification, implying that a series of long-term changes accumulate over time leading to entirely new species.
- (5) Molecular, anatomical, and genetic evidence exists for evolution. Evolution provides a scientific explanation for the fossil record, genetic similarities, and anatomical similarities between species. These records provide a source of information regarding the length of time required for evolution to occur as well as to the degree of relatedness between species.
- (6) Natural selection is the mechanism through which evolution occurs. Evolution occurs through a systematic process called natural selection. Natural selection incorporates concepts of population, variation and mutation, and survival.
- (5) Current evolutionary thinking supports multiple theories regarding the pace and direction of evolution. Evolutionary experts still debate the pace and direction of evolution. Some scientists argue that evolution is punctuated or that it has “fits and starts;” whereas other scientists contend that evolution occurs at a relatively constant rate over time. In addition, evolution of a species does not necessarily infer a “progression” for that species. Evolution occurs due to environmental and genetic factors that directly influence a species and those factors change over time. Accordingly, evolution occurs without any set direction or sense of advancement.

TEKS Biology 7 (The student knows the theory of evolution) cannot be achieved fully without student understanding of these seven basic concepts. Overall, an emphasis on the evolution-related TEKS should provide students a comprehensive knowledge of evolution as defined by these 7 concepts. However, an emphasis on the 5 concepts

identified in the clouds included in the strand map would expand and solidify this knowledge.

Benchmarks for Science Literacy

Benchmarks for Science Literacy (American Association for the Advancement of Science, 1993) notes the following in regard to the teaching of evolution:

- Students should first be familiar with the evidence of evolution so that they will have an informed basis for judging different explanation.
- Before natural selection is proposed as a mechanism for evolution, students must recognize the diversity and apparent relatedness of species.
- To appreciate how natural selection can account for evolution, students have to understand the important distinction between the selection of an *individual* with a certain trait and the changing proportions of that trait in *populations*.
- Virtually all scientists accept the general concept of evolution of a species but scientists do have different opinions on how fast and by what mechanisms evolution proceeds.
- A separate issue altogether is how life itself began, a detailed mechanism for which has not yet emerged. (p. 122)

The *Benchmarks* recommend that in grades K-2, biological diversity be emphasized and student curiosity about dinosaurs and fossils be used to develop the concept that there are life forms that no longer exist. In grades 3-5, this document recommends a focus on the consequences of different features of organisms in relationship to their survival and reproduction. Comparisons of fossils and living organisms are recommended for use in developing student understanding of the similarities embedded within the diversity of both present and past species.

The *Benchmarks* recommend that students in grades 6-8 should learn more about the several lines of evidence for evolution, the heritability of traits and the effect of selection. Also, students should develop an understanding of the how evolutionary change has occurred over geologic time.

The *Benchmarks* for grades 9-12 indicate that the overall concept of evolution, the mechanisms of evolution, molecular evidence for evolution, natural selection as a mechanism for evolution, heritable characteristics at the molecular and whole-organism levels, genetic recombination and mutations, and the nature of evolution should be emphasized.

Teaching about Evolution and the Nature of Science

In order to clarify the differences between facts, theories, laws, and principles, this document (National Academy of Science, 1998, p. 5) provides the following definition:

Fact: In science an observation that has been repeatedly confirmed.

Law: A descriptive generalization about how some aspect of the natural world behaves under stated circumstances.

Hypothesis: A testable statement about the natural world that can be used to build more complex inferences and explanations.

Theory: In science, a well-substantiated explanation of some aspect of the natural world that can incorporate facts, laws, inferences, and tested hypotheses.

Other definitions provided by this document are as follows:

Evolution: Change in the hereditary characteristics of groups of organisms over the course of generations. (Darwin referred to this process as “descent with modification.”)

Species: In general, a group of organisms that can potentially breed with each other to produce fertile offspring and cannot breed with the members of other such groups.

Variation: Genetically determined differences in the characteristics of members of the same species.

Natural Selection: Greater reproductive success among particular members of a species arising from genetically determined characteristics that confer an advantage in a particular environment. (p. 13)

Science and Creationism

This document (National Academy of Science, 1999) answers the question “Is evolution a fact or a theory?” as follows:

The theory of evolution explains how life on Earth has changed. In scientific terms, “theory” does not mean “guess” or “hunch” as it does in everyday usage. Scientific theories are explanations of natural phenomena built up logically from testable observations and hypotheses. Biological evolution is the best scientific explanation we have for the enormous range of observations about the natural world.

Scientists most often use the word “fact” to describe an observation. But scientists can also use fact to mean something that has been tested or observed so many times that there is no longer a compelling reason to keep testing or looking for examples. The occurrence of evolution in this sense is a fact. Scientists no longer question whether descent with modification occurred because the evidence supporting the idea is so strong. (p. 28)

Exemption from Instruction

Texas Education Agency policy regarding student exemption from study is as follows:

- (a) A parent is entitled to remove the parent's child temporarily from a class or other school activity that conflicts with the parent's religious or moral beliefs if the parent presents or delivers to the teacher of the parent's child a written statement authorizing the removal of the child from the class or other school activity. A parent is not entitled to remove the parent's child from a class or other school activity to avoid a test or to prevent the child from taking a subject for an entire semester.
- (b) This section does not exempt a child from satisfying grade level or graduation requirements in a manner acceptable to the school district and the agency. (TEA, 2000, p. 11)

References

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