UTeach Primary

CURRÍCULUM

UTeach

WE PREPARE TEACHERS. THEY CHANGE THE WORLD.

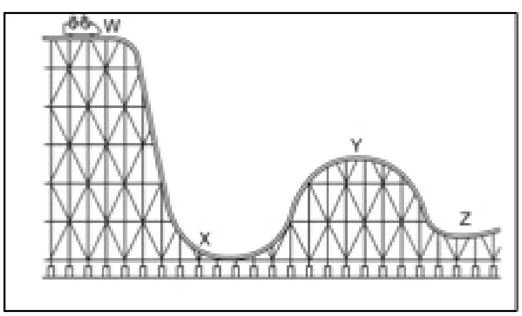
Our Vision

Imagine a science curriculum that incorporates the process of questioning and discovery into a hands-on learning environment. Students are asked questions like, “Why is the moon half dark at night?” or “How does a telescope work?” and then discuss their ideas. They are given equipment to investigate the phenomenon, either recreating it or building replicas in the form of models. Individual memorization is less important than the team of participants working together to acquire the data reliably and critiquing each other’s ideas to develop the most accurate explanation for the phenomena they’ve seen.

Curriculum

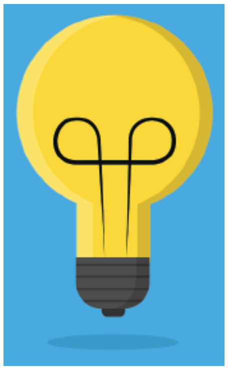
Our curriculum uses two underlying concepts to unify the sciences as an extended investigation into a broad range of systems ranging from the solar system, the Earth, life forms that inhabit our planet, and so on. Too often, science is presented as a series of disjointed facts, and we fail to make the connections between the concepts of various disciplines. In reality, all scientists are knowledgeable biologists, geologists, astronomers, chemists, and physicists. We have developed our curriculum upon two important themes: Matter and Energy, building on work of Goldberg et al. [Goldberg, F., Otero, V., and Robinson, S. (2007), Physics and Everyday Thinking, It's About Time Publishing.] and Nelson [Nelson, G. (2008), "Physics and Everyday Thinking as a Model for Introductory Biology and Geology Courses," presented at PTEC-Northwest Regional Conference, Seattle, Washington: October 10, 2008] to extend this analysis to all the sciences.

Often, we teach the term of energy and the idea of conservation of energy without developing why it is important or how it manifests itself. Consider the question shown here from the state of Texas' 2006 TAKS test. It concerns the topic of energy, specifically the conservation of energy and how it can be transformed from one type (gravitational potential energy) to another (kinetic energy). It is answered correctly by 85% of students in a pre-test to our pre-service elementary teachers' class, indicating their successful training over years on this kind of problem.



At which point on the roller coaster will the car have the greatest amount of kinetic energy?

Yet, students mastering this question can fail to apply a basic understanding of energy to other systems.



A common student misconception is that a light bulb grows warm when connected to a electrical circuit because the battery to which it is connected is hot, therefore a source of thermal energy. Such a misconception misses the basic forms of energy and how energy can be transformed from one type (electrical or chemical potential) to another (light and heat).

Another common student misconception is that a cup of coffee cools because "more cold gets in to it"; instead, students should recognize thermal energy as a form of energy that is transferred to the surrounding air in the room, and pause to consider the source of the thermal energy in the coffee in the first place.

Which of these are composed of two or more different substances that are chemically combined in a definite ratio?

F Compounds
G Mixtures
H Elements
J Solutions
K Minerals
L Atoms
M Molecules

Consider the TAKS question at left which, according to standard curricula in chemistry, is properly answered as "F," a "compound," but would be answered by any practicing physicist as "M," a molecule or by many geologists as "K," a mineral. If students cannot wade through the jargon, it is unlikely that they will come to understand the basic fact that all of physics, chemistry, geology, and biology depend upon the atomic or particle model of matter.

Big Ideas Rather than Jargon

Rather than emphasize terminology, it is important to use the particle nature of matter to explain phenomena. The coffee cools, for example, because of collisions between particles in the coffee and particles in the air.

The drum, for example, transmits sound to our ears by converting the kinetic energy of the mallet to the kinetic energy of the drumhead, which in turn causes collisions of particles in the air, a seeds effect that finally reaches our ear.

The seedling, for example, becomes a tree because it takes in carbon from the surrounding air. This last example is particularly poignant, because when students in our courses are initially shown a large chunk of wood and asked "where does all the stuff in this chunk of wood come from; in other words, from where does a tree acquire all its matter?" many will promptly respond "water" and "sunlight," and many will reply "the soil." Only 15% correctly cite the carbon dioxide in air. Yet, 90% of our students correctly answered "C" to the question of which chemical compound represents the food energy in this process.

$CO_2 + H_2O$ + sunlight energy —> $C_6H_{12}O_6 + O_2$

Which molecule in the equation represents food energy made by plants?

A. Carbon dioxide
B. Water
C. Glucose
D. Oxygen

Interdisciplinary Curriculum

Energy is an important fundamental concept in science, and so it appropriately acts as a common linking thread throughout the Hands-on-Science curriculum. In the first course we spend a significant percentage of our time discussing how energy flows from one form to another in physical systems.

That idea is applied in other courses after the foundation of energy flow and energy conservation has been laid out. Energy, force, and energy conservation must be understood before concepts like how buoyancy can be developed since it builds upon an understanding of balanced vs. unbalanced forces.

By the time we end the third course, which discusses energy in biological systems, participants are quite comfortable discussing topics such as how radiant energy from the sun becomes chemical energy in plants (ex., photosynthesis) or thermal energy in our atmosphere (ex., greenhouse effect).

As we learn about gravity as a force and how it is related to gravitational potential energy and conservation of energy, we develop ideas about how the force of gravity depends on mass. Later, we build upon these concepts to understand gravity beyond earth, which then allows us to talk about planetary orbits.

Throughout discussions of physics, chemistry, and biology content, we build on the small particle model of heat movement (conduction and convection) to explain the third method of heat movement: radiation. This is interesting because it is a departure from explaining heat movement though a medium (solid, gas, or liquid) and instead explains movement through a vacuum. The whole topic is necessary because the biology workshop delves into a discussion of energy entering living systems, and this energy comes in the form of visible light traveling to Earth from the Sun through the vacuum of space. Without an understanding of the small particle model, we would have no context for developing our ideas of radiation.

The study of fossils is another topic that builds upon content from multiple disciplines. In our geology discussions, we learn that different geologic strata can be identified by their similar fossils. This emphasizes the layering of the Earth and also the long time spans involved in the Earth's history. In our biology work, we discuss fossils as examples of the tremendous variation of organisms present on the earth at different times and build upon the previously developed concepts to explain the diverse lineages that can be traced through time to today.

The Four Courses

NSC306J Energy and Force

Introduces the idea of energy, how energy is transferred into various forms of potential and kinetic energy in a system through interactions (forces), and the small particle model. Students then apply these concepts in three examples: gravity, electrical circuits, and sound waves.

NSC306K Chemistry and Geology

Students learn that electrostatic potential energy is what holds our world together utilizing the small particle model of matter. They learn that elements, molecules and atoms are what make up our universe. We discuss the Periodic Table and show how chemical bonds have the potential to store chemical energy. In geology, we introduce the concepts of buoyancy and heat transfer mechanisms of convection and conduction. We then use these concepts to understand how these forces result in the movements of Earth's crustal plates producing earthquakes, volcanoes and Earth's surface topography. We finish with the concepts of the rock cycle and geologic time.

NSC306L Biological Systems

The themes of matter and energy are integrated into the major course topics of radiant energy, energy transfer in living things, characteristics of living things, compartments, inheritance, and variation.

NSC306M Astronomy and Earth Climate

Building upon the inquiry-based methodology and content of previous Hands-on-Science courses (NSC 306J and NSC 306K are prerequisites), we will tackle the fields of astronomy and Earth science this semester. In this semester, we study several topics, including phenomena on Earth and beyond – how distant objects interact and how we perceive them. We consider light and how it behaves, as well as gravity. We also address the appearance of things in the sky—size and scale of objects in the universe and how their distance affects how we see them, the movement of the Sun and stars in the sky, and our perception of Moon phases. Closer to home, we talk about our own observations of patterns such as the changing seasons, and differences between weather and climate.

Inquiry as Our Form of Instruction

It takes years to develop the analytical thinking skills and the skeptical intuition of a scientist. This process can begin in early grades, harnessing the natural curiosity of children and their free ability to ask radical questions that adults are sometimes too hesitant to ask. Our curriculum borrows upon research-based curricula (Goldberg 2007 and Goldberg 2008), which encourages that kind of questioning and thinking.

At the same time, our curriculum encourages another hallmark skill of scientists: evidence-based reasoning. While many content-heavy courses fall prey to direct instruction (lecture) of scientific concepts in order to cover large amounts of material, such an approach encourages children to become memorizers of facts, and to experience science as an unrelated series of facts lacking synthesis. Instead, our curriculum is structured around the central principle that it is better to discover new phenomena and to learn the art of constructing models, which account for these phenomena.

Inquiry as Our Form of Instruction

In so doing, we encourage students to cite evidence in support of ideas, and we encourage teachers to think of instruction not as the articulation of facts, but rather the process of leading children through experiments that will allow them to construct the big ideas in the sciences. In our courses and our workshops, participants collaborate in teams to develop a scientifically rigorous model that explains energy in the world around us. Each participant is required to bring her own ideas to the table, to test those ideas with real measurements, and work together as a group toward an understanding of what we learned. In the end, we will, like scientists, used evidence-based reasoning to formulate a consensus on the lesson of the day.

Class Structure

Purpose
Each day will begin with a central question posed to the class. For example, "Why do objects fall?" "How do we generate electrical energy in our homes?" and so on. There is no work to be done here, just an introduction, a statement of the problem to be addressed.

Initial Ideas
In this section of a workshop or class, participants will be asked a couple questions for individuals to consider and groups to discuss at their group tables. In some cases, we will share our responses as a class. The purpose of this time is not to "get the right answer." Rather, the intention is to brainstorm as to what's going on, put our ideas on the table, and have in our minds what are other people's explanations for a given concept. There may be some class confusion at this stage, and the instructor, acting as moderator, will highlight the ideas presented with the hope that the remainder of the day's activities will provide the evidence to support one group's idea over another's.

Class Structure

Collecting Evidence

Participants conduct two or three experiments each class or workshop. Each experiment will hopefully challenge you to ask questions about what is going on, and also give you some experimental evidence for you to use when you develop a model of the phenomenon we're studying. Along the way, while you are conducting these experiments, you will be asked some guiding questions to help you think your way through the activities.

Summarizing Questions

At the end of each activity, we have prepared a set of 4–8 questions for participants to work through in their small groups. The questions range from testing understanding of various key points encountered in the experiments to helping develop a scientific model that explains all the data we just took in our groups. After groups have discussed their ideas on these questions, each group prepares diagrams or explanations on white boards to share with the rest of the class. Each group is encouraged to copy data, graphs, etc. to help them make their point and provide more convincing evidence in support of their explanation to the questions or models of the big idea of the day. The discussion that ensues should clarify some of the points raised at the beginning of class in the Initial Ideas section. Ideally, the participants will have discovered the big idea for the day, relying on the instructor only to moderate the class discussion.