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The Origin of *Launching Learners in Science*

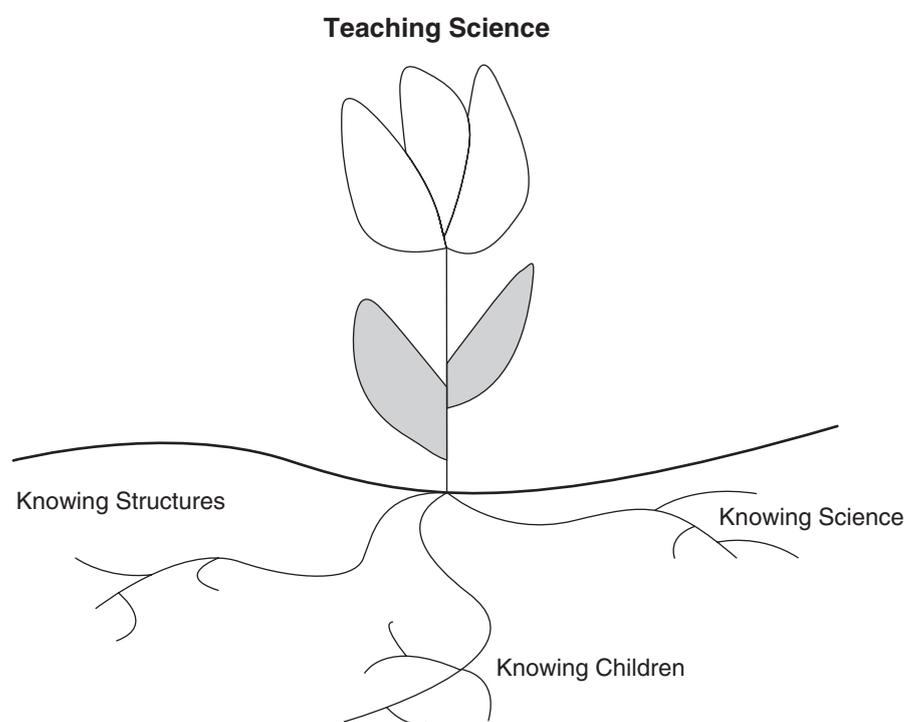
A new approach to learning science can look very promising; it can offer refreshing new ideas and innovative strategies. Yet too often the approach does not really take root in the classroom. Like a plant with no roots, different approaches to teaching and learning science come and go as if they were blown over by gusting winds. Given too little time and support to truly understand the ideas surrounding the approach, teachers often give up on them and go back to something more familiar, or they go on to the next promising approach they are expected to use. Fully embracing and valuing an approach to teaching science requires understanding the theories and research behind it and thinking about your beliefs about teaching science, thus growing some roots!

The approach to teaching science described in this book is not a curriculum but rather a way of thinking about teaching and learning science that can be incorporated into curricula presented by individual schools, districts, or states. It is based on the broader constructivist approach, especially as presented in the *National Science Education Standards (NSES)* of the National Research Council (NRC), and it consists of three main components. These components are (1) knowing science, (2) knowing children and how they learn, and (3) knowing flexible structures that facilitate learning and teaching science in an environment where individual learners' and local, state, and district needs are met. Note that in each component the word "knowing" is used rather than "knowledge." What is the

difference? Although subtle, the difference is important. For us, “knowing” implies a continued journey within the domain being learned whereas “knowledge” implies an ending. One of the professional development standards cited in the *National Science Education Standards* is “The development of the understanding and ability for lifelong learning” (NRC, 1996, p. 4). Indeed, we hope you continue to learn about science, children learning science, and teaching science throughout your career as an educator.

Each of the three components within this approach is a vital piece of teaching science, and each is grounded in experience, theory, and ongoing research. In other words, each component has a purpose and an origin. You might wonder why someone who teaches science would need to know about the origin of these components. Why not merely give teachers a list of lessons and content to do in their classrooms with directions to follow? If you look back at the components listed above, each of them is very broad and yet personalized to individual teachers. Your understandings of science are different from those of your colleagues. The students that you teach have different understandings of science as well as different levels of maturity. Your schools, school districts, and states each have different requirements for teaching science. Following a list of directions will not allow you to meet the needs of your students, your school, or your self. Truly knowing what you believe about science, children learning science, and teaching science will help you meet all of these individual needs. Take some time to think

Figure 1.1 Growing Roots



Teaching science requires some “roots” including knowing structures that facilitate learning, knowing children, and knowing science.

about what you believe about teaching and learning science now. Where did *your* beliefs originate? Who or what influenced those beliefs?

The components surrounding this text originated from a great variety of sources and experiences including everything from working in actual science laboratories to reading about maturation according to Piaget to teaching all levels of students. And, although the components are our “roots” keeping us grounded when new ideas come along, they are also always growing, and we are always learning.

Perhaps one of the most influential sources of the three components of this text is the *National Science Education Standards*. These standards provide a great deal of structure and direction with regard to knowing science, knowing children and how they learn science, and knowing flexible structures to teach science effectively. However, they also provide much choice and decision-making responsibility for teachers and students. “The content embodied in the Standards can be organized and presented with many different emphases and perspectives in many different curricula. They bring coordination, consistency, and coherence to the improvement of science education” (NRC, 1996, p. 3). Make sure to look at the outline of the Standards presented at the end of this chapter.

Other important influences include several educational researchers both past and present. John Dewey’s writings help us advocate learning as an active process of constructing knowledge (Dewey, 1938). Jean Piaget’s research helps us weave child development into thinking and planning for classrooms, and Vygotsky’s research helps us think about child development in the context of social learning. More recently, Ron Ritchhart helps us develop thinking routines to empower students in classrooms to actually think rather than just take in information. Rich Stiggins promotes assessment *for* learning rather than *of* learning, helping us to design effective assessment tools.

Our vision of the structures needed to teach science in classrooms comes from newly developed brain research and theorists such as Gardner, Perkins, and others who have helped us realize that intelligence is about more than language and mathematical ability. Our vision comes also from recreating the scientific method, transforming it into more than a step-by-step process, and from actually using routines such as the 5E cycle and plan-do-review (plan-do-review is a routine rather than an approach. It is a thinking routine promoted in Chapter 8) in classrooms. These theories, among many others, provide the origins for our ideas, both theoretical and practical, and you will see these ideas come through as you read each section.

In addition, we have been influenced by our own experiences in laboratories and in classrooms. The stories told throughout this book really happened and will hopefully encourage you to trust and learn from your own experiences. We hope that the stories, theories, and Standards are an origin for many great science experiences to come for you! *Teaching is a thinking profession*, and you must do the thinking about science, children, and structures in order to create meaningful science experiences with your students.

Let’s begin with the content area we are addressing: science. What does it mean to know science? Who needs to know science?

■ KNOWING SCIENCE

At first glance, you might think knowing science means being able to answer science questions, or maybe you envision someone who does well in science courses. Take some time to think about this component from another angle. *Why* would someone who teaches science need to “know science?” How will knowing science influence how you teach?

My understanding of “knowing science” was influenced a great deal during one experience with my sister. Perhaps her words will help you as well. In the snowy mountains of Colorado on vacation, my family sat in a lodge while taking a break from skiing. We talked about what my sister Jennifer would do after finishing her PhD in biology. We eagerly offered our suggestions—I thought she would be a great biology teacher at a college, my mother suggested applying to a college where she could teach and do research, and my father suggested a small college where there would not be as much pressure to write grants. As the three of us excitedly talked about the possibilities, we suddenly realized that Jennifer’s face was crinkled and doubtful. The world stopped for a moment, and everything got quiet. Jennifer said quietly and with conviction, “But . . . I want to *do* science.” She did not want to be in the background of science, learning knowledge from others and then dispensing it. She wanted to come up with her own questions and design experiments to answer them. She wanted to wonder and plan and discover. She wanted to actively do science. And that is what she did. Jennifer went on to do a post-doc in a laboratory in Germany, carrying out a great deal of scientific research. I became an elementary teacher who learned a lot of science with my students. Those six words my sister had practically whispered forever changed how I think about teaching. Learners, like scientists, need to *do* science, too.

Knowing science is much more than being able to answer test questions about scientific facts. It is about knowing enough about the science topic to be able to ask good questions, helping children find possible answers through creative experimentation, and giving children opportunities to share what they find. Teachers and learners of science must have a “familiarity with a discipline’s concepts, theories, and models; an understanding of how knowledge is generated and justified; and an ability to use these understandings to engage in new inquiry” (Bransford & Donovan, 2005, p. 398). The key words there are “*engage in new inquiry*.” Einstein emphasized the importance of imagination as a tool creating opportunities to go beyond observation (Bransford & Donovan, 2005). Knowing science must be novel, creative, and imaginative rather than a set of steps to follow.

The *National Science Education Standards* states, “Teachers must have theoretical and practical knowledge and abilities about science, learning and teaching science” (NRC, 1996, p. 28). This book is designed to help you begin knowing science both as a topic and as a way into inquiry. Instead of dispensing knowledge to students in your classroom, be an active inquirer with them! Wonder aloud with your students! Try out experiments! Be a learner of science!

The component of knowing science surfaces throughout this book in places like Chapter 2, “The Nature of Science,” where you will begin to think about science as a noun and a verb; in Chapter 3 where you will

begin to look at your own content and concept knowledge within science and how these may influence how you teach science; and in Chapter 9 where you will begin to put your understandings to work as you develop science workshops. Those chapters, however, are the places where the component of knowing science is most obvious. Look for the component “knowing science” throughout the book!

As of right now, begin to think of yourself as a learner or researcher. What questions do you have about teaching science? How will knowing science and what it means to do science change your classroom? How will you become an inquirer about the students you work with?

KNOWING CHILDREN AND HOW THEY LEARN ■

Sometimes we teachers forget what teaching is all about. We come up with fantastic lesson plans and opportunities for learning but neglect our roles as learners of children. We, as educators, must know who our students are as people, who they are developmentally, and who they are scientifically before we can create opportunities for them to learn science. “Actions of teachers are deeply influenced by their understanding of and relationships with students” (NRC, 1996, p. 29).



Photo 1.1 Relationships With Children

Mrs. Farley shares in this student's excitement while observing snails.

In order to create the best opportunities for students to learn science, we must build relationships with them. “Teaching becomes figuring out how to see and listen to each kid, one kid at a time, so that the kid can reach the goals for himself or herself” (Littky, 2004, p. 13). What is the student interested in studying? Does the student reflect best through writing, drawing, or talking about experiences? What experiences have

students had with rocks, light, or animals? What kinds of support and messages do they receive at home about learning in general and specifically about science? Did they get breakfast this morning? Of course, there are a million questions, and, with many students in classrooms, knowing students individually may take some time. However, taking time to consciously listen and consciously think about each as an individual as you plan science lessons is invaluable.

Another important piece to know about your students is where they are in their journey of maturation. Indeed, there will be a wide range of levels of development in each grade. However, there will also be large ranges within single classrooms and within different activities. Jean Piaget, an educational psychologist, developed stages of development discussed in Chapter 4. Many times, teachers use the stages as a way of opting out of certain activities. For example, you may hear statements like, "That is not developmentally appropriate for young children" or "That will be too easy for students at this level." We would like to advocate development as another way to *know* students rather than as a deterrent to their learning. Knowing how a student thinks about objects in the world will help provide you with information about what questions to ask, why students might not understand something, and how to proceed so that they can begin to understand. It will also help you guide them as you inquire about science topics.

Students come to science with preconceptions that are important for you to know as well. "Students bring conceptions of everyday phenomena to the classroom that are quite sensible, but scientifically limited or incorrect" (Bransford & Donovan, 2005, p. 399). In a video produced by the Harvard-Smithsonian Center for Astrophysics, 21 of 23 randomly selected Harvard students gave the wrong answer to the question, "What causes the seasons?" (Littky, 2004). Their preconceived, but incorrect, ideas involved the earth being closer to the sun during summer and further from it during winter. Their experiences would seem to support their preconceptions. After all, our experiences support the idea that distance from a heat source affects temperature. The closer we stand to sources of heat, the greater is the heat (Bransford & Donovan, 2005). The important aspect of this example is not that students gave wrong answers but that they had misconceptions. It is important that we as teachers know our students and their ideas about science well enough to help them have experiences that question their incorrect or incomplete ideas and give them opportunities to amend them.

In addition to knowing students individually, it is important to know what you believe about how students learn in general. Just as knowing science influences how you develop lessons in a classroom, so does knowing what it means to learn. There are many beliefs about how people learn. As stated earlier, this book is formed around the principals of constructivism. Constructivism is the belief that learners must construct or develop their own knowledge through experience. Grounded in the work of Piaget, Vygotsky, Bruner, and Dewey, the constructivist model of learning emphasizes active construction of meaning rather than a passive collection of information. Knowledge is not given to the learner, but rather the learner creates meaning through actively experiencing and then thinking about those experiences. "Learning science is something students do, not something that is done to them" (NRC, 1996, p. 20).

You will find more information about knowing students and how they learn in many of the chapters of this book including all of Part II: Construction Ahead: Influences on Learning. In the chapters that make up that section, you will learn more about maturation and its influence on learning science, more about social interaction and the importance of a balance between adult and student control, and more about what it means to learn actively. All of these topics are vital to teaching science well.

If you believe that learning requires individual construction of knowledge fostered through experience and inquiry, the question then becomes what the teacher needs to know about creating structures so that this happens. What is different about teaching within the constructivist paradigm? How might your classroom look if you believe teachers need to be learners and that learning involves the active construction of knowledge?

KNOWING STRUCTURES THAT FACILITATE LEARNING AND TEACHING SCIENCE

In many science classrooms today, routines are often about making sure everyone is on the same page or about remembering the same facts. The *National Science Education Standards* (NRC, 1996) encourage less emphasis on rigidly following curriculum and treating all students alike and more emphasis on selecting and adapting curriculum and understanding and responding to individual student needs.

Changing Emphases

Take some time to think about how and where you learn best. What structures are in place? What did the teacher do to facilitate your needs? Littky (2004) believes that “We learn best when we care about what we are doing, when we have choices. We learn best when the work has meaning to us, when it matters. We learn best when we are using our hands and minds” (p. 28). How does this translate into the classroom?

Many, many structures and environments facilitate learning science. The environment and structures put into place in one science classroom may look very different from those in another, yet both teachers may have the same goals in mind. The point is not to have classrooms that look and sound the same or to have every teacher using the same techniques. The point is to know that the structures you choose *will* influence learning. If you believe that students learn science best by participating physically, how will you structure that in a classroom? In other words, *why* are you using the structures you are using?

The structures presented in this book (see Part III and IV) are based on brain research, constructivist principles of learning, and the individual needs of learners and teachers. They are flexible and allow teachers to be creative and thoughtful. However, they also provide a strong structure for classroom management, assessment, and meeting the needs of all individual learners.

Recently, there has been much research done on brain-based learning, (see Jensen, 2005.) With new technologies available, many researchers have been able actually to see connections being made and changes happening in the brain at different stages of maturity. Brain research is in its

Table 1.1 Changing Emphasis

<i>Less Emphasis On</i>	<i>More Emphasis On</i>
Treating all students alike and responding to the group as a whole	Understanding and responding to individual student's interests, strengths, experiences, and needs
Rigidly following curriculum	Selecting and adapting curriculum
Focusing on student acquisition of information	Focusing on student understanding and use of scientific knowledge, ideas, and inquiry processes
Presenting scientific knowledge through lecture, text, and demonstration	Guiding students in active and extended scientific inquiry
Asking for recitation of acquired knowledge	Providing opportunities for scientific discussion and debate among students
Testing students for factual information at the end of the unit or chapter	Continuously assessing student understanding
Maintaining responsibility and authority	Sharing responsibility for learning with students
Supporting competition	Supporting a classroom community with cooperation, shared responsibility, and respect
Working alone	Working with other teachers to enhance the science program

SOURCE: *National Science Education Standards*, by the National Research Council, 1996, Washington, DC: National Academy Press, p. 52. Reprinted courtesy of the National Science Foundation.

early stages, but theorists believe that one way to implement brain friendly strategies is to have an environment in which students feel good. Lighting, atmosphere, and surroundings should convey messages of safety and commitment to learning. Students should be immersed in complex experiences with a lot of stimuli. Students should actively analyze their experiences and use their knowledge out in the world. And, above all, students should be able to review and repeat experiences (Franklin, 2005).

The work in the field of brain-based learning connects nicely to the principles of constructivism. "Using knowledge in the world" and "reviewing and repeating experiences" allows for much knowledge to be constructed, and the atmosphere and safe places to learn provide opportunities for all students to construct that knowledge. Many teachers I have spoken to talk about constructivism as a method. They talk about hands-on materials and their students actively participating. When it comes right down to it, constructivism is not a method. It is a way of thinking about learning. Constructivist classrooms look very different at times. Reading a book or answering (some) worksheet questions can be helping students to construct knowledge. What is the difference between reading a book or answering worksheet questions constructively and non-constructively?



Photo 1.2 Experiencing Magnetism
Students construct knowledge about magnets.

In some sense, the activity itself does not make something constructivist or not. However, the order of events does matter within constructivist learning structures. Why might this be the case? Note the difference between a lesson in which the teacher gives the students a set of wires, a battery, and some lightbulbs and teaches them how to put these together to light the bulb versus a lesson in which the teacher gives the students a set of wires, a battery, and some lightbulbs and asks them how many different ways there are to get the bulb to light. The activity is the same, the materials are the same, but the order is different. How? In the first lesson, the students are given the procedure and then asked to repeat it. In the second lesson, students are asked to experience the physical and mindful manipulation before they are asked to understand it.

Providing structures for learning that create opportunities for children to construct knowledge helps and, in a sense requires, individualization of learning. Students who have had more experiences with electricity, for example, will be able to work creatively on more than one way to light the bulb while students who have never had experiences with electricity will be able to learn the more basic concepts. Both of these students are doing the same lesson at the same time, and their needs are being met.

The specific structures within this book include key science experiences (Chapter 7), thinking routines (Chapter 8), and workshops (Chapter 9). The key experiences were developed as a way to help you create lessons that promote the processes of science as well as to help you assess students' strengths and needs in science. Thinking routines (Ritchhart, 2002) help students become aware of the thinking they are doing and allow them to gain thinking dispositions such as the sensitivity to know when there is a problem, the ability to know and do science, and the inclination to keep learning (Williams, 2004). Finally, workshops were developed to help you create science opportunities that revolve around specific science content,

that promote effective classroom management, and that emphasize individual differences. In addition, there are also structures in Part IV that will help you develop both assessment opportunities and a physical setting that promotes learning.

Throughout this chapter, we have talked about roots and origins, flexible structures, and constructing knowledge. Now we need to address the other structures in place that teachers deal with daily. Those structures are the ones created through district, state, and national standards. Perhaps this discussion is key to understanding the entire book! We have created this book to give you a way “in to” teaching science. Just like a swimmer, a teacher needs a place to dive in; this book is that place. After reading the book, you must make this approach to teaching science your own based on your beliefs about knowing science, knowing students, knowing structures that promote learning, and combining those beliefs with your district, state, and national standards. Chapter 12 will help you sift through all of these ideas and begin to create a place where all students can learn science with you!

Before “jumping in,” reflect on the ideas presented so far. Think of the *National Science Education Standards*, the theories and visions of the researchers who influenced the pieces of this book, and add to this what you believe about learning. Try to construct a picture in your mind of what a science classroom developed around these ideas looks like, sounds like, and feels like. What components of the approach do you already use? Which ones seem to stand out as particularly valuable for elementary science? What other questions do you need to have answered before you continue reading?

■ OUTLINE OF THE NSES SCIENCE CONTENT STANDARDS

I. Unifying Concepts and Processes

U1 *Systems, Order, and Organization*

1. Goal is to think and analyze in terms of systems
2. Types and levels of organization provide useful ways of thinking about the world

U2 *Evidence, Models, and Explanation*

1. Evidence consists of observations and data on which to base scientific explanations
2. Models are tentative schemes corresponding to real objects, events, or classes of events that have explanatory power
3. Scientific explanation incorporates scientific knowledge and new evidence (from observations, experiments, or models) into internally consistent, logical statements

U3 *Constancy, Change, and Measurement*

1. Most things change but some are constant (e.g., “c,” charge on electron, etc.)
2. Energy can be transferred
3. Changes can be quantified; different systems of measurement
4. “Scale includes understanding that characteristics, properties, or relationships within a system might change as its dimensions are increased or decreased”
5. Rate: comparing one quantity with another or change of one quantity with the whole

U4 *Evolution and Equilibrium*

1. Evolution is series of changes accounting for present form, function, or characteristics
2. Equilibrium is state in which forces and changes occur in opposite and off-setting directions

U5 *Form and Function*

1. Form and function are complementary aspects of objects, organisms, and systems in the natural and designed world

IIA. Science as Inquiry**A1** *Abilities to Do Science*

1. Asking questions about objects, organisms, and events in environment
2. Plan and conduct a simple investigation
3. Employ simple equipment and tools to gather data and extend senses
4. Use data to construct a reasonable explanation
5. Communicate investigations and explanations

A2 *Understandings About Scientific Inquiry*

1. Review and ask question about results of other scientists’ work

IIIB. Physical Science Content Standards**B1** *Properties of Objects and Materials*

1. Objects have many observable properties—size, weight, color, shape, etc.
2. Objects are made of one or more materials that have properties
3. Materials can exist in different states—gas, liquid, solid

B2 Position and Motion of Objects

1. Locate objects relative to others or the background
2. Motion can be described by tracing position over time
3. Position and motion changed by push and pull
4. Sound produced by vibration

B3 Light, Heat, Electricity, and Magnetism

1. Light travels in straight lines; reflection, refraction, absorption
2. Heat produced in many ways; transferred by conduction
3. Electricity in circuits produces light, heat, sound, magnetism
4. Magnets attract and repel each other and certain materials

IIIC. Life Science Standards**C1 Characteristics of Organisms**

1. Basic needs
2. Different structures for growth, survival, and reproduction
3. Behavior influenced by internal and external cues

C2 Life Cycles of Organisms

1. Organisms have different life cycles
2. Plants and animals resemble their parents
3. Characteristics are inherited and others are the result of interactions with some environment

C3 Organisms and Their Environments

1. All animals depend on plants
2. Organisms depend on biotic and abiotic factors; when these change, organisms change
3. All organisms change their environment
4. Humans depend on their environment

IVD. Earth and Space Science**D1 Properties of Earth Materials**

1. Materials are solid rocks and soils, water, and gases of the atmosphere
2. Soil properties such as color, texture, water retention, etc.
3. Fossils provide evidence for life and environments of long ago

D2 *Objects in the Sky*

1. Sun, moon, stars, clouds, birds, airplanes
2. Sun provides light and heat to maintain temperature of earth

D3 *Changes in Earth and Sky*

1. Surface of earth changes—slow and fast (e.g., erosion and landslides)
2. Weather changes daily and over seasons
3. Objects in sky have patterns of movement

VE. Science and Technology**E1** *Abilities of Technological Design*

1. Identify a simple problem
2. Propose a solution
3. Implement proposed solutions
4. Evaluate a product or design
5. Communicate a problem, design, and solution

E2 *Understanding About Science and Technology*

1. Understanding the basis of and need for the above “abilities”
2. Ability to distinguish between natural objects and objects made by humans

VIF. Science in Personal and Social Perspective**F1** *Personal Health*

1. Safety and security are basic needs of humans
2. We have some responsibility for our own health
3. Nutrition is essential to health
4. Different substances can damage the body and its functions

F2 *Characteristics and Changes in Populations*

1. Human populations include groups living in a particular location
2. Population sizes can increase or decrease

F3 *Types of Resources*

1. We get resources from biotic and abiotic sources
2. Resources can be natural, man-made, or non-material (peace, quiet, safety, etc.)
3. Resources can be limited

F4 Changes in Environments

1. Environments are space, conditions, and factors affecting survival
2. Changes can be natural or induced by humans (But if all organisms change their environments, then is it not “natural” for humans to change theirs?)
3. Environments change at different rates

F5 Science and Technology in Local Challenges

1. Continuously inventing new ways of doing things, solving problems, and doing work
2. Science and technology have greatly improved food quality and quantity

VIIIG. History and Nature of Science**G1 Science as a Human Endeavor**

1. Science has been practiced for a long time
2. Men and women have made contributions throughout history
3. While much has been learned, much remains to be learned
4. People choose science as career

Conversation Starters

- How are the National Science Education Standards connected to knowing science, knowing children and how they learn, and knowing flexible structures that facilitate learning and teaching science in an environment where individual learners' and local, state, and district needs are met? Create a web showing the connections.
- Where do your beliefs about teaching science come from? Make a timeline of important events leading to these beliefs.
- What does it mean to know science? What does someone know who is scientifically literate?
- Write a definition of learning.
- List all of the structures that might influence learning science in a classroom.
- Take a science lesson and change the order so that it allows students to construct their own knowledge. Take a lesson that does this and change the order so that students are merely receiving information.
- What is your definition of a standard? Share it with two other people who defined a standard. What were the differences? Similarities? Why is it important to know what a standard is?