Benchmarks for Science Literacy Grades Three through Five Grade Band Descriptions

The Universe

Students should begin to develop an inventory of the variety of things in the universe. Planets can be shown to be different from stars in two essential ways—their appearance and their motion. When a modest telescope or pair of binoculars is used instead of the naked eyes, stars only look brighter—and more of them can be seen. The brighter planets, however, clearly are disks. (Not very large disks except in good-sized telescopes, but impressive enough after seeing a lot of stars.) The fixed patterns of stars should be made more explicit, although learning the constellation names is not important in itself. When students know that the star patterns stay the same as they move across the sky (and gradually shift with the seasons), they can then observe that the planets change their position against the pattern of stars.

Once students have looked directly at the stars, moon, and planets, use can be made of photographs of planets and their moons and of various collections of stars to point out their variety of size, appearance, and motion. No particular educational value comes from memorizing their names or counting them, although some students will enjoy doing so. Nor should students invest much time in trying to get the scale of distances firmly in mind. As to numbers of stars in the universe, few children will have much of an idea of what a billion is; thousands are enough of a challenge. (At this stage, a billion means more than a person could ever count one-at-a-time in an entire lifetime.)

Students' grasp of many of the ideas of the composition and magnitude of the universe has to grow slowly over time. Moreover, in spite of its common depiction, the sun-centered system seriously conflicts with common intuition. Students may need compelling reasons to really abandon their earth-centered views. Unfortunately, some of the best reasons are subtle and make sense only at a fairly high level of sophistication.

The Earth

During this period, students can begin to learn some of the surface features of the earth and also the earth's relation to the sun, moon, and other planets. Films, computer simulations, a planetarium, and telescopic observations will help, but it is essential that all students, sometimes working together in small groups, make physical models and explain what the models show. At the same time, students can begin learning about scale (counting, comparative distances, volumes, times, etc.) in interesting, readily understood activities and readings. However, scale factors larger than thousands, and even the idea of ratios, may be difficult before early adolescence.

An important point to be made along the way is that one cannot determine how the solar system is put together just by looking at it. Diagrams show what the system would look like if people could see it from far away, a feat that cannot be accomplished. Telescopes and other instruments do provide information, but a model is really needed to make sense out of the information. (The realization that people are not able to see, from the outside, how the solar system is constructed will help students understand the basis for the Copernican Revolution when the topic arises later.)

In making diagrams to show, say, the relative sizes of the planets and the distances of the planets from the sun, students may try to combine them using a single scale—and quickly become frustrated. Perhaps this can lead to a discussion of the general limits of graphic methods (including photographs) for showing reality. In any case, at this stage a rough picture of the organization of the solar system is enough.

Water offers another important set of experiences for students at this level. Students can conduct investigations that go beyond the observations made in the earlier grades to learn the connection between liquid and solid forms, but recognizing that water can also be a gas, while much more difficult, is still probably accessible. Perhaps the main thrust there is to try to figure out where water in an open container goes. This is neither self-evident nor easy to detect. But the water cycle is of such profound importance to life on earth that students should certainly have experiences that will in time contribute to their understanding of evaporation, condensation, and the conservation of matter. In these years, students should accumulate more information about the physical environment, becoming familiar with the details of geological features, observing and mapping locations of hills, valleys, rivers, etc., but without elaborate classification. Students should also become adept at using magnifiers to inspect a variety of rocks and soils. The point is not to classify rigorously but to notice the variety of components.

Students should now observe elementary processes of the rock cycle—erosion, transport, and deposit. Water and sand boxes and rock tumblers can provide them with some firsthand examples. Later, they can connect the features to the processes and follow explanations of how the features came to be and still are changing. Students can build devices for demonstrating how wind and water shape the land and how forces on materials can make wrinkles, folds, and faults. Films of volcanic magma and ash ejection dramatize another source of buildup.

The Structure of Matter

The study of materials should continue and become more systematic and quantitative. Students should design and build objects that require different properties of materials. They should write clear descriptions of their designs and experiments, present their findings whenever possible in tables and graphs (designed by the students, not the teacher), and enter their data and results in a computer database.

Objects and materials can be described by more sophisticated properties—conduction of heat and electricity, buoyancy, response to magnets, solubility, and transparency. Students should measure, estimate, and calculate sizes, capacities, and weights. If young children can't feel the weight of something, they may believe it to have no weight at all. Many experiences of weighing (if possible on increasingly sensitive balances)—including weighing piles of small things and dividing to find the weight of each—will help. It is not obvious to elementary students that wholes weigh the same as the sum of their parts. That idea is preliminary to, but far short of, the conservation principle to be learned later that weight doesn't change in spite of striking changes in other properties as long as all the parts (including invisible gases) are accounted for.

With magnifiers, students should inspect substances composed of large collections of particles, such as salt and talcum powder, to discover the unexpected details at smaller scales. They should also observe and describe the behavior of large collections of pieces—powders, marbles, sugar cubes, or wooden blocks (which can, for example, be "poured" out of a container) and consider that the collections may have new properties that the pieces do not.

Energy Transformation

Investing much time and effort in developing formal energy concepts can wait. The importance of energy, after all, is that it is a useful idea. It helps make sense out of a very large number of things that go on in the physical and biological and engineering worlds. But until students have reached a certain point in their understanding of bits and pieces of the world, they gain little by having such a tool. It is a matter of timing.

The one aspect of the energy story in which students of this age can make some headway is heat, which is produced almost everywhere. In their science and technology activities during these years, students should be alerted to look for things and processes that give off heat—lights, radios, television sets, the sun, sawing wood, polishing surfaces, bending things, running motors, people, animals, etc.—and then for those that seem not to give off heat. Also, the time is appropriate to explore how heat spreads from one place to another and what can be done to contain it or shield things from it.

Students' ideas of heat have many wrinkles. In some situations, cold is thought to be transferred rather than heat. Some materials may be thought to be intrinsically warm (blankets) or cold (metals). Objects that keep things warm—such as a sweater or mittens—may be thought to be sources of heat. Only a continuing mix of experiment and discussion is likely to dispel these ideas.

Students need not come out of this grade span understanding heat or its difference from temperature. In this spirit, there is little to be gained by having youngsters refer to heat as heat energy. More important, students should become familiar with the warming of objects that start out cooler than their environment, and vice versa. Computer labware probes and graphic displays that detect small changes in temperature and plot them can be used by students to examine many instances of heat exchange. Because many students think of cold as a substance that spreads like heat, there may be some advantage in translating descriptions of transfer of cold into terms of transfer of heat.

Motion and Forces

Students should continue describing motion. And they can be more experimental and more quantitative as their measurement skills sharpen. Determining the speed of fast things and slow things can present a challenge that students will readily respond to. They also can work out for themselves some of the general relationships between force and change of motion and internalize the notion of force as a push or pull of one thing on another—whether rubber bands, magnets, or explosions.

Students should also increase their inventory of examples of periodic motion and perhaps devise ways of measuring different rates of vibration. And students should use prisms to see that white light produces a whole "rainbow" of colors. (The idea that white light is "made up of" different colors is difficult and should be postponed to later grades.) There is nothing to be gained at this stage, however, from linking light to wave motion. The main notion to convey here is that forces can act at a distance. Students should carry out investigations to become familiar with the pushes and pulls of magnets and static electricity. The term gravity may interfere with students' understanding because it often is used as an empty label for the common (and ancient) notion of "natural motion" toward the earth. The important point is that the earth pulls on objects.

Diversity of Life

Students should have the opportunity to learn about an increasing variety of living organisms, both the familiar and the exotic, and should become more precise in identifying similarities and differences among them. Although the emphasis can still be on external features, finer detail than before should be included. Hand lenses, introduced earlier, should now be routinely used by students. Microscopes should come into use, not to study cell structure but to begin exploring the world of organisms that cannot be seen by the unaided eye. Fortunately, wealth of films exists to supplement direct observation.

As students become more familiar with the characteristics of more and more organisms, they should be asked to invent schemes for classifying them--but without using the Linnean classification system. Hopefully, their classification schemes will vary according to the uses made of them as well as according to gross anatomy, behavior patterns, habitats, and other features. The aim is to move students toward the realization that there are many ways to classify things but how good any classification is depends on its usefulness. A scheme is useful if it contributes either to making decisions on some matter or to a deeper understanding of the relatedness of organisms. Classification schemes will, of course, vary with purpose (pets/nonpets; edible/nonedible).

Students can begin to look for ways in which organisms in one habitat differ from those in another and consider how some of those differences are helpful to survival. The focus should be on the consequences of different features of organisms for their survival and reproduction. The study of fossils that preserve plant and animal structures is one approach to looking at characteristics of organisms. Evidence for the similarity within diversity of existing organisms can draw upon students' expanding knowledge of anatomical similarities and differences.

Heredity

Students should move from describing individuals directly (she has blue eyes) to naming traits and classifying individuals with respect to those traits (eye color: blue). Students can be encouraged to keep lists of things that animals and plants get from their parents, things that they don't get, and things that the students are not sure about either way. This is also the time to start building the notion of a population whose members are alike in many ways but show some variation.

Cells

Students' experiences should expand to include the observation of microscopic organisms, so the scale of magnification should increase to 30- or 100-power (dissection scope or low power on microscopes). Watching microorganisms is always informative, but some events are so rare that prepared materials are a necessity. Students can observe films of living cells growing and dividing, taking in substances, and changing direction when they run into things. Some students may reason that because these tiny cells are alive, they probably have the same needs as other, larger organisms. That can stimulate discussions about how single-celled organisms satisfy their need for food, water, and air.

Interdependence of Life

Students should explore how various organisms satisfy their needs in the environments in which they are typically found. They can examine the survival needs of different organisms and consider how the conditions in particular habitats can limit what kinds of living things can survive. Their studies of interactions among organisms within an environment should start with relationships they can directly observe. By viewing nature films, students should see a great diversity of life in different habitats.

Flow of Matter and Energy

Students should begin to notice that substances may change form and move from place to place, but they never appear out of nowhere and never just disappear. Questions should encourage students to consider where substances come from and where they go and to be puzzled when they cannot account for the origin or the fate of a substance. It's all right to start students on chains of what eats what in various environments, but labeling the steps in the chain as energy transfer is not necessary. Transfers of energy at this level are better illustrated in physical systems; biological energy transfer is far too complicated.