[1]Connections to Benchmarks for Science Literacy

American Association for the Advancement of Science

1. The Nature of Science
   - A. The Scientific World View
     - K-2 When a science investigation is done the way it was done before, we expect to get a very similar result.
     - K-2 When a science investigation is done again in a different place, we expect to get a very similar result.
     - 3-5 Sometimes similar investigations give different results because of differences in the things being investigated, the methods used, or the circumstances in which the investigation is carried out, and sometimes just because of uncertainties in observations. It is not always easy to tell which.
     - 3-5 Science is a process of trying to figure out how the world works by making careful observations and trying to make sense of those observations.
     - 6-8 When similar investigations give different results, the scientific challenge is to judge whether the differences are trivial or significant, and it often takes further studies to decide.
     - 6-8 Even with similar results, scientists may wait until an investigation has been repeated many times before accepting the results as correct.
     - 6-8 Scientific knowledge is subject to modification as new information challenges prevailing theories and as a new theory leads to looking at old observations in a new way.
     - 6-8 Some scientific knowledge is very old and yet is still applicable today.
   - B. Scientific Inquiry
     - K-2 People can often learn about things around them by just observing those things carefully, but sometimes they can learn more by doing something to the things and noting what happens.
     - K-2 Tools such as thermometers, magnifiers, rulers, or balances often give more information about things than can be obtained by just observing things unaided.
     - 3-5 Scientific investigations may take many different forms, including observing what things are like or what is happening somewhere, collecting specimens for analysis, and doing experiments.
     - 3-5 Because we expect science investigations that are done the same way to produce the same results, when they do not, it is important to try to figure out why.
     - 3-5 One reason for following directions carefully and for keeping records of one's work is to provide information on what might have caused the differences in investigations.
     - 6-8 If more than one variable changes at the same time in an experiment, the outcome of the experiment may not be clearly attributable to any one of the variables. It may not always be possible to prevent outside variables from influencing the outcome of an investigation (or even to identify all of the variables).
     - 6-8 Collaboration among investigators can often lead to research designs that are able to deal with situations where it is not possible to control all of the variables.
     - 9-12 Investigations are conducted for different reasons, including to explore new phenomena, to check on previous results, to test how well a theory predicts, and to compare theories.
     - 9-12 Hypotheses are widely used in science for choosing what data to pay attention to and what additional data to seek, and for guiding the interpretation of the data (both new and previously available).
     - 9-12 Sometimes, scientists can control conditions in order to obtain evidence. When that is not possible for practical or ethical reasons, they try to observe as wide a range of natural occurrences as possible to be able to discern patterns.
   - C. The Scientific Enterprise
     - K-2 Everybody can do science and invent things and ideas.
     - K-2 In doing science, it is often helpful to work with a team and to share findings with others. All team members should reach their own individual conclusions, however, about what the findings mean.

3-5 Science is an adventure that people everywhere can take part in, as they have for many centuries.
3-5 Clear communication is an essential part of doing science. It enables scientists to inform others about their work, expose their ideas to criticism by other scientists, and stay informed about scientific discoveries around the world.
3-5 Doing science involves many different kinds of work and engages men and women of all ages and backgrounds.
9-12 Progress in science and invention depends heavily on what else is happening in society
9-12 History often involves scientific and technological developments.

2. The Nature of Mathematics
   A. Patterns and Relationships
      K-2 Circles, squares, triangles, and other shapes can be found in things in nature and in things that people build.
      K-2 Patterns can be made by putting different shapes together or taking them apart. Patterns may show up in nature and in the things people make.
      K-2 Things move, or can be made to move, along straight, curved, circular, back-and-forth, and jagged paths.
      3-5 Mathematics is the study of quantity and shape and is useful for describing events and solving practical problems.
   B. Mathematics, Science, and Technology
      6-8 Mathematics is helpful in almost every kind of human endeavor—from laying bricks to prescribing medicine or drawing a face.
   C. Mathematical Inquiry
      K-2 Numbers and shapes can be used to tell about things.
      3-5 Quantities and shapes can be used to describe objects and events in the world around us.
3. The Nature Of Technology
   A. Technology and Science
      K-2 Tools are used to do things better or more easily and to do some things that could not otherwise be done at all. In technology, tools are used to observe, measure, and make things.
      K-2 When trying to build something or to get something to work better, it usually helps to follow directions if there are any or to ask someone who has done it before for suggestions.
      3-5 Measuring instruments can be used to gather accurate information for making scientific comparisons of objects and events and for designing and constructing things that will work properly.
      3-5 Technology extends the ability of people to change the world: to cut, shape, or put together materials; to move things from one place to another; and to reach farther with their hands, voices, senses, and minds. The changes may be for survival needs such as food, shelter, and defense, for communication and transportation, or to gain knowledge and express ideas.
      6-8 Engineers, architects, and others who engage in design and technology use scientific knowledge to solve practical problems. They also usually have to take human values and limitations into account.
      9-12 Technological problems and advances often create a demand for new scientific knowledge, and new technologies make it possible for scientists to extend their research in new ways or to undertake entirely new lines of research. The very availability of new technology itself often sparks scientific advances.
      9-12 Mathematics, creativity, logic and originality are all needed to improve technology.
      9-12 Technology usually affects society more directly than science does because technology solves practical problems and serves human needs (and also creates new problems and needs)
      9-12 One way science affects society is by stimulating and satisfying people's curiosity and enlarging or challenging their views of what the world is like.
      9-12 Engineers use knowledge of science and technology, together with strategies of design, to solve practical problems. Scientific knowledge provides a means of estimating what the behavior of things will be even before they are made. Moreover, science often suggests new kinds of behavior that had not even been imagined before, and so leads to new technologies
   B. Design and Systems
      K-2 People may not be able to actually make or do everything that they can design.
      3-5 There is no perfect design. Designs that are best in one respect (safety or ease of use, for example) may be inferior in other ways (cost or appearance). Usually some features must be sacrificed to get others.

3-5 Even a good design may fail. Sometimes steps can be taken ahead of time to reduce the likelihood of failure, but it cannot be entirely eliminated.
3-5 The solution to one problem may create other problems.
6-8 Design usually requires taking into account not only physical and biological constraints, but also economic, political, social, ethical, and aesthetic ones
6-8 All technologies have effects other than those intended by the design, some of which may have been predictable and some not.
6-8 Almost all control systems have inputs, outputs, and feedback.
6-8 The essence of control is comparing information about what is happening to what people want to happen and then making appropriate adjustments. This procedure requires sensing information, processing it, and making changes
9-12 The value of any given technology may be different for different groups of people and at different points in time.

C. Issues in Technology

K-2 People, alone or in groups, are always inventing new ways to solve problems and get work done. The tools and ways of doing things that people have invented affect all aspects of life.
3-5 Transportation, communications, nutrition, sanitation, health care, entertainment, and other technologies give large numbers of people today the goods and services that once were luxuries enjoyed only by the wealthy. These benefits are not equally available to everyone.
3-5 Factors such as cost, safety, appearance, environmental impact, and what will happen if the solution fails also must be considered in technological design.
3-5 Technologies often have drawbacks as well as benefits. A technology that helps some people or organisms may hurt others-either deliberately (as weapons can) or inadvertently (as pesticides can).
3-5 Because of their ability to invent tools and processes, people have an enormous effect on the lives of other living things.
6-8 Technology cannot always provide successful solutions for problems or fulfill every human need.
6-8 Technology is largely responsible for the great revolutions in agriculture, manufacturing, sanitation and medicine, warfare, transportation, information processing, and communications that have radically changed how people live and work.
6-8 New technologies increase some risks and decrease others. Some of the same technologies that have improved the length and quality of life for many people have also brought new risks.
6-8 Rarely are technology issues simple and one-sided. Relevant facts alone, even when known and available, usually do not settle matters entirely in favor of one side or another. That is because the contending groups may have different values and priorities. They may stand to gain or lose in different degrees, or may make very different predictions about what the future consequences of the proposed action will be.
6-8 Societies influence what aspects of technology are developed and how these are used. People control technology (as well as science) and are responsible for its effects.
6-8 Scientific laws, engineering principles, properties of materials, and construction techniques must be taken into account in designing engineering solutions to problems.
9-12 Social and economic forces strongly influence which technologies will be developed and used. Which will prevail is affected by many factors, such as personal values, consumer acceptance, patent laws, the availability of risk capital, the federal budget, local and national regulations, media attention, economic competition, and tax incentives.
9-12 Some scientists and engineers are comfortable working in situations in which some secrecy is required, but others prefer not to do so. It is generally regarded as a matter of individual choice and ethics, not one of professional ethics.
9-12 Human inventiveness has brought new risks as well as improvements to human existence.

4. The Physical Setting

B. The Earth

6-8 Everything on or anywhere near the earth is pulled toward the earth's center by gravitational force.

C. Process That Shape the Earth

6-8 Human activities, such as reducing the amount of forest cover, increasing the amount and variety of chemicals released into the atmosphere, and intensive farming, have changed the earth's land, oceans, and atmosphere. Some of these changes have decreased the capacity of the environment to support some life forms.

D. The Structure of Matter

K-2 Objects can be described in terms of their properties. Some properties, such as hardness and flexibility, depend upon what material the object is made of, and some properties, such as size and shape, do not.

3-5 All materials have certain physical properties, such as strength, hardness, flexibility, durability, resistance to water and fire, and ease of conducting heat.

E. Energy Transformations

3-5 When two objects are rubbed against each other, they both get warmer. In addition, many mechanical and electrical devices get warmer when they are used

3-5 When warmer things are put with cooler ones, the warmer things get cooler and the cooler things get warmer until they all are the same temperature.

3-5 When warmer things are put with cooler ones, heat is transferred from the warmer ones to the cooler ones.

3-5 A warmer object can warm a cooler one by contact or at a distance.

6-8 Whenever energy appears in one place, it must have disappeared from another. Whenever energy is lost from somewhere, it must have gone somewhere else. Sometimes when energy appears to be lost, it actually has been transferred to a system that is so large that the effect of the transferred energy is imperceptible

6-8 Energy can be transferred from one system to another (or from a system to its environment) in different ways: 1) thermally, when a warmer object is in contact with a cooler one; 2) mechanically, when two objects push or pull on each other over a distance; 3) electrically, when an electrical source such as a battery or generator is connected in a complete circuit to an electrical device; or 4) by electromagnetic waves.

6-8 Thermal energy is transferred through a material by the collisions of atoms within the material. Over time, the thermal energy tends to spread out through a material and from one material to another if they are in contact. Thermal energy can also be transferred by means of currents in air, water, or other fluids. In addition, some thermal energy in all materials is transformed into light energy and radiated into the environment by electromagnetic waves; that light energy can be transformed back into thermal energy when the electromagnetic waves strike another material. As a result, a material tends to cool down unless some other form of energy is converted to thermal energy in the material.

6-8 Energy appears in different forms and can be transformed within a system. Motion energy is associated with the speed of an object. Thermal energy is associated with the temperature of an object. Gravitational energy is associated with the height of an object above a reference point. Elastic energy is associated with the stretching or compressing of an elastic object. Chemical energy is associated with the composition of a substance. Electrical energy is associated with an electric current in a circuit. Light energy is associated with the frequency of electromagnetic waves.

9-12 Although the various forms of energy appear very different, each can be measured in a way that makes it possible to keep track of how much of one form is converted into another. Whenever the amount of energy in one place diminishes, the amount in other places or forms increases by the same amount..

F. Motion

K-2 Things move in many different ways, such as straight, zigzag, round and round, back and forth, and fast and slow.

K-2 The way to change how something is moving is to give it a push or a pull.

K-2 Things that make sound vibrate.

3-5 Changes in speed or direction of motion are caused by forces.

3-5 The greater the force is, the greater the change in motion will be. The more massive an object is, the less effect a given force will have.

3-5 How fast things move differs greatly. Some things are so slow that their journey takes a long time; others move too fast for people to even see them.

6-8 An unbalanced force acting on an object changes its speed or direction of motion, or both.
6-8 If the force acts toward a single center, the object's path may curve into an orbit around the center.
9-12 The change in motion (direction or speed) of an object is proportional to the applied force and inversely proportional to the mass.
9-12 All motion is relative to whatever frame of reference is chosen, for there is no motionless frame from which to judge all motion.
9-12 Whenever one thing exerts a force on another, an equal amount of force is exerted back on it.
9-12 In most familiar situations, frictional forces complicate the description of motion, although the basic principles still apply.
9-12 Any object maintains a constant speed and direction of motion unless an unbalanced outside force acts on it.

G. Forces of Nature
K-2 Things near the earth fall to the ground unless something holds them up.
K-2 Magnets can be used to make some things move without being touched.
3-5 The earth's gravity pulls any object on or near the earth toward it without touching it
3-5 Without touching them, a magnet pulls on all things made of iron and either pushes or pulls on other magnets.
3-5 Without touching them, an object that has been electrically charged pulls on all other uncharged objects and may either push or pull other charged objects.
6-8 Every object exerts gravitational force on every other object. The force depends on how much mass the objects have and on how far apart they are. The force is hard to detect unless at least one of the objects has a lot of mass.
6-8 Electric currents and magnets can exert a force on each other.
9-12 In many conducting materials, such as metals, some of the electrons are not firmly held by the nuclei of the atoms that make up the material. In these materials, applied electric forces can cause the electrons to move through the material, producing an electric current. In insulating materials, such as glass, the electrons are held more firmly, making it nearly impossible to produce an electric current in those materials.
9-12 At very low temperatures, some materials become superconductors and offer no resistance to the flow of electrons.
9-12 Magnetic forces are very closely related to electric forces and are thought of as different aspects of a single electromagnetic force. Moving electrically charged objects produces magnetic forces and moving magnets produces electric forces.
9-12 The interplay of electric and magnetic forces is the basis for many modern technologies, including electric motors, generators, and devices that produce or receive electromagnetic waves.

6. The Human Organism. .

D. Learning
K-2 People use their senses to find out about their surroundings and themselves. Different senses give different information.
K-2 People can learn from each other by telling and listening, showing and watching, and imitating what others do.
3-5 Human beings have different interests, motivations, skills, and talents.
3-5 Human beings can use the memory of their past experiences to make judgments about new situations.
3-5 Learning means using what one already knows to make sense out of new experiences or information, not just storing the new information in one's head.
6-8 Learning often results from two perceptions or actions occurring at about the same time. The more often the same combination occurs, the stronger the mental connection between them is likely to be. Occasionally a single vivid experience will connect two things permanently in people's minds.
6-8 Language and tools enable human beings to learn complicated and varied things from others.

8. The Designed World

A. Agriculture
3-5 Modern technology has increased the efficiency of agriculture so that fewer people are needed to work on farms than ever before.

B. Materials and Manufacturing
- K-2 Some kinds of materials are better than others for making any particular thing. Materials that are better in some ways, such as stronger or cheaper, may be worse in other ways, such as heavier or harder to cut.
- K-2 Several steps are usually involved in making things.
- K-2 Tools are used to help make things, and some things cannot be made at all without tools. Each kind of tool has a special purpose.
- 3-5 Naturally occurring materials such as wood, clay, cotton, and animal skins may be processed to change their properties.
- 3-5 Humans have produced a wide variety of materials, such as steel, plastic, and nylon, that do not appear in nature.
- 3-5 Although many things are still made by hand in some parts of the world, almost everything in the most technologically developed countries is now produced using machines that are automated. By using machinery, the time required to make a product and its cost can be greatly reduced.
- 6-8 The choice of materials for a job depends on their properties.
- 6-8 Automation, including the use of robots, has changed the nature of work in most fields, including manufacturing. As a result, the demand for workers with some knowledge and skills has decreased while the demand for workers with other knowledge and skills has increased. Furthermore, as the pace of innovation has increased, workers have needed to learn new skills throughout their careers.
- 9-12 Manufacturing processes have been changed by improved tools and techniques based on more thorough scientific understanding, increases in the forces that can be applied and the temperatures that can be reached, and the availability of electronic controls that make operations occur more rapidly and consistently.
- 9-12 Increased knowledge of the properties of particular molecular structures helps in the design and synthesis of new materials for special purposes

C. Energy Sources and Use
- 3-5 Moving air and water can be used to run machines.
- 3-5 Sunlight is used to run many devices
- 3-5 Some people try to reduce the amount of fuels they use in order to conserve resources, reduce pollution, or save money.
- 6-8 Transformations and transfers of energy within a system usually result in some energy escaping into its surrounding environment. Some systems transfer less energy to their environment than others during these transformations and transfers.
- 9-12 When selecting fuels, it is important to consider the relative advantages and disadvantages of each fuel.

9. The Mathematical World

A. Numbers
- K-2 Numbers can be used to count things, place them in order, measure them, or name them.
- 3-5 It is possible (and often useful) to estimate quantities without determining them exactly.
- 3-5 In some situations, "0" means none of something, but in others it may be just the label of some point on a scale, such as a number line.
- 3-5 Specifying a quantity requires both a number and a unit.

B. Symbolic Relationships
- K-2 Similar patterns may show up in many places in nature and in the things people make.
- K-2 Sometimes changing one thing causes changes in something else. In some situations, changing the same thing in the same way has the same result.
- 6-8 Rates of change can be computed from differences in magnitudes and vice versa.

C. Shapes
- K-2 Circles, squares, triangles, spheres, cubes, cylinders and other shapes can be observed in things found in nature and in things that people build.
- 3-5 Length can be thought of as unit lengths joined together, area as a collection of unit squares, and volume as a set of unit cubes.
- 3-5 If 0 and 1 are located on a line, any other number can be depicted as a position on the line.
- 3-5 Graphical display of numbers may make it possible to spot patterns that are not otherwise obvious, such as cycles and trends.

3-5 Objects can be described in terms of their shape or the shapes of their parts
3-5 Scale drawings show shapes and compare locations of things very different in size.
6-8 Some of the properties an object has depend on its shape: triangular shapes tend to make structures rigid, and spheres give the least possible boundary for a given amount of interior volume.

D. Uncertainty

K-2 Some things are more likely to happen than others.
K-2 Some events can be predicted well and some cannot.
K-2 Sometimes people aren't sure what will happen because they don't know everything that might be having an effect.
K-2 Often a person can find out about a group of things by studying just a few of them.
3-5 Some predictions can be based on what is known about the past, assuming that conditions are pretty much the same now.
3-5 Events can be described in terms of being more or less likely, impossible, or certain.
6-8 How probability is estimated depends on what is known about the situation. Estimates can be based on data from similar conditions in the past or on the assumption that all the possibilities are known.

E. Reasoning

3-5 One way to think about something is to compare it to something more familiar.
6-8 Sometimes people invent a generalization to summarize a set of observations. But sometimes people overgeneralize, imagining generalizations on the basis of too few observations.
6-8 An analogy has some likenesses to but also some differences from the real thing.
9-12 Once a person believes in a general rule, he or she may be more likely to notice cases that agree with it and to overlook cases that don't.
9-12 Because computers can store, retrieve, and process large amounts of data, they can rapidly perform a long series of logic steps. They are therefore being used increasingly to help experts solve complex problems that would otherwise be very difficult or impossible to solve. Not all logic problems, however, can be solved by computers

10. Historical Perspectives

A. Displacing the Earth from the Center of the Universe

6-8 Because every object is moving relative to some other object, no object has a unique claim to be at rest. Therefore, the idea of absolute motion or rest is misleading.

B. Uniting the Heavens and Earth

9-12 Isaac Newton, building on earlier descriptions of motion by Galileo, Kepler, and others, created a unified view of force and motion in which motion everywhere in the universe can be explained by the same few rules. Newton's system was based on the concepts of mass, force, and acceleration; his three laws of motion relating them; and a physical law stating that the force of gravity between any two objects in the universe depends only upon their masses and the distance between them.
9-12 Newton's mathematical analysis of gravitational force and motion showed that planetary orbits had to be the very ellipses that Kepler had proposed two generations earlier.
9-12 The Newtonian model made it possible to account for such diverse phenomena as tides, the orbits of planets and moons, the motion of falling objects, and the earth's equatorial bulge.

11. Common Themes

A. Systems

K-2 Most things are made of parts.
K-2 Something may not work if some of its parts are missing.
K-2 When parts are put together, they can do things that they couldn't do by themselves.
3-5 In something that consists of many parts, the parts usually influence one another.
3-5 Something may not work well (or at all) if a part of it is missing, broken, worn out, mismatched, or misconnected.
6-8 A system can include processes as well as things.
6-8 Thinking about things as systems means looking for how every part relates to others. The output from one part of a system (which can include material, energy, or information) can become the input to other parts. Such feedback can serve to control what goes on in the system as a whole.
6-8 Any system is usually connected to other systems, both internally and externally. Thus a system may be thought of as containing subsystems and as being a subsystem of a larger system.

6-8 Some portion of the output of a system may be fed back to that system's input.
9-12 A system usually has some properties that are different from those of its parts, but appear because of the interaction of those parts.
9-12 Understanding how things work and designing solutions to problems of almost any kind can be facilitated by systems analysis. In defining a system, it is important to specify its boundaries and subsystems, indicate its relation to other systems, and identify what its input and its output are expected to be.

B. Models
K-2 Many toys are like real things in some ways but not others. They may not be the same size, are missing many details, or are not able to do all of the same things.
K-2 A model of something is different from the real thing but can be used to learn something about the real thing.
K-2 One way to describe something is to say how it is and isn't like something else.
3-5 Geometric figures, number sequences, graphs, diagrams, sketches, number lines, maps, and oral and written descriptions can be used to represent objects, events, and processes in the real world.
3-5 A model of something is similar to, but not exactly like, the thing being modeled. Some models are physically similar to what they are representing, but others are not.

C. Constancy and Change
K-2 Objects change in some ways and stay the same in some ways.
K-2 People can keep track of some things, seeing where they come from and where they go.
K-2 An object can change in various ways, such as in size, weight, color, or temperature
3-5 Some features of things may stay the same even when other features change.
3-5 Things change in steady, repetitive, or erratic ways—or sometimes in more than one way at the same time..
3-5 Often the best way to tell which kinds of change are happening is to make a table or graph of measurements.
6-8 A system may stay the same because nothing is influencing it or the influences on it are balanced.
6-8 Many systems contain feedback mechanisms that serve to keep changes within specified limits.
9-12 Symmetry (or the lack of it) may determine properties of many objects, from molecules and crystals to organisms and designed structures.

D. Scale
3-5 Finding out what the largest and the smallest values of something are is often as informative as knowing what the usual value is.
6-8 Some properties of an object depend on its length, some depend on its area, and some depend on its volume.
6-8 As the complexity of any system increases, gaining an understanding of it depends increasingly on summaries, such as averages and ranges, and on descriptions of typical examples of that system.

12. Habits of Mind

A. Values and Attitudes
K-2 Raise questions about the world and be willing to seek answers to these questions by making careful observations and trying things out.
3-5 Offer reasons for their findings and consider reasons suggested by others.
6-8 Know that often different explanations can be given for the same observations, and it is not always possible to tell which one is correct.

B. Computation and Estimation
K-2 Use whole numbers in ordering, counting, identifying, measuring, and describing objects and events.
3-5 Judge whether measurements and computations of quantities such as length, weight, or time are reasonable by comparing them to familiar values.

C. Manipulation and Observation
K-2 Make something out of paper, cardboard, cloth, wood, plastic, metal, or existing objects that can actually be used to perform a task.
K-2 Measure the length in whole units of objects using rulers and tape measures.
3-5 Choose appropriate common materials for making simple mechanical constructions and repairing things.

D. Communication Skills

K-2 Describe and compare real-world objects in terms of number, shape, texture, size, weight, color, and motion.

K-2 Draw pictures that portray some features of the thing being described.

9-12 Use and correctly interpret relational terms such as *if . . . then . . . , and, or, sufficient, necessary, some, every, not, correlates with, and causes*.

E. Critical-Response Skills

K-2 Ask "How do you know?" in appropriate situations and attempt reasonable answers when others ask the same question.

3-5 Recognize when comparisons might not be fair because some conditions are not kept the same.

1. American Association for the Advancement of Science, *Benchmarks for Science Literacy, Project 2061*. As of 2019. Available online http://www.project2061.org/publications/bsl/online/index.php