Science DOK Levels

Please note that, in science, "knowledge" can refer both to content knowledge and knowledge of scientific processes. This meaning of knowledge is consistent with the *National Science Education Standards* (NSES), which terms "Science as Inquiry" as its first Content Standard.

Level 1 (Recall and Reproduction) requires the recall of information, such as a fact, definition, term, or a simple procedure, as well as performance of a simple science process or procedure. Level 1 only requires students to demonstrate a rote response, use a well-known formula, follow a set procedure (like a recipe), or perform a clearly defined series of steps. A "simple" procedure is well defined and typically involves only one step. Verbs such as "identify," "recall," "recognize," "use," "calculate," and "measure" generally represent cognitive work at the recall and reproduction level. Simple word problems that can be directly translated into and solved by a formula are considered Level 1. Verbs such as "describe" and "explain" could be classified at different DOK levels, depending on the complexity of what is to be described and explained.

A student answering a Level 1 item either knows the answer or does not: that is, the item does not need to be "figured out" or "solved." In other words, if the knowledge necessary to answer an item automatically provides the answer to it, then the item is at Level 1. If the knowledge needed to answer the item is not automatically provided in the stem, the item is at least at Level 2. Some examples that represent, but do not constitute all of, Level 1 performance are:

- Recall or recognize a fact, term, or property.
- Represent in words or diagrams a scientific concept or relationship.
- Provide or recognize a standard scientific representation for simple phenomenon.
- Perform a routine procedure, such as measuring length.

Level 2 (Skills and Concepts) includes the engagement of some mental processing beyond recalling or reproducing a response. The content knowledge or process involved is **more complex** than in Level 1. Items require students to make some decisions as to how to approach the question or problem. Keywords that generally distinguish a Level 2 item include "classify," "organize," "estimate," "make observations," "collect and display data," and "compare data." These actions imply **more than one step**. For example, to compare data requires first identifying characteristics of the objects or phenomena and then grouping or ordering the objects. Level 2 activities include making observations and collecting data; classifying, organizing, and comparing data; and organizing and displaying data in tables, graphs, and charts. Some action verbs, such as "explain," "describe," or "interpret," could be classified at different DOK levels, depending on the complexity of the action. For example, interpreting information from a simple graph, requiring reading information from the graph, is a Level 2. An item that requires interpretation from a complex graph, such as making decisions regarding features of the graph that need to be considered and how information from the graph can be aggregated, is at Level 3. Some examples that represent, but do not constitute all of, Level 2 performance, are:

- Specify and explain the relationship between facts, terms, properties, or variables.
- Describe and explain examples and non-examples of science concepts.
- Select a procedure according to specified criteria and perform it.
- Formulate a routine problem, given data and conditions.
- Organize, represent, and interpret data.

Level 3 (Strategic Thinking) requires reasoning, planning, using evidence, and a higher level of thinking than the previous two levels. The cognitive demands at Level 3 are complex and abstract. The complexity does not result only from the fact that there could be multiple answers, a possibility for both Levels 1 and 2, but because the multi-step task requires more demanding reasoning. In most instances, requiring students to explain their thinking is at Level 3; requiring a very simple explanation or a word or two should be at Level 2. An activity that has more than one possible answer and requires students to justify the response they give would most likely be a Level 3. Experimental designs in Level 3 typically involve more than one dependent variable. Other Level 3 activities include drawing conclusions from observations; citing evidence and developing a logical argument for concepts; explaining phenomena in terms of concepts; and using concepts to solve non-routine problems. Some examples that represent, but do not constitute all of Level 3 performance, are:

- Identify research questions and design investigations for a scientific problem.
- Solve non-routine problems.
- Develop a scientific model for a complex situation.
- Form conclusions from experimental data.

Level 4 (Extended Thinking) involves high cognitive demands and complexity. Students are required to make several connections—relate ideas within the content area or among content areas—and have to select or devise one approach among many alternatives to solve the problem. Many on-demand assessment instruments will not include any assessment activities that could be classified as Level 4. However, standards, goals, and objectives can be stated in such a way as to expect students to perform extended thinking. “Develop generalizations of the results obtained and the strategies used and apply them to new problem situations,” is an example of a grade 8 objective that is a Level 4. Many, but not all, performance assessments and open-ended assessment activities requiring significant thought will be Level 4.

Level 4 requires complex reasoning, experimental design and planning, and probably will require an extended period of time either for the science investigation required by an objective, or for carrying out the multiple steps of an assessment item. However, the extended time period is not a distinguishing factor if the required work is only repetitive and does not require applying significant conceptual understanding and higher-order thinking. For example, if a student has to take the water temperature from a river each day for a month and then construct a graph, this would be classified as a Level 2 activity. However, if the student conducts a river study that requires taking into consideration a number of variables, this would be a Level 4. Some examples that represent, but do not constitute all of, a Level 4 performance are:

- Based on data provided from a complex experiment that is novel to the student, deduct the fundamental relationship between several controlled variables.
- Conduct an investigation, from specifying a problem to designing and carrying out an experiment, to analyzing its data and forming conclusions.

Examples Applied to Science Objectives and Assessment Items

Sample Science Objectives

Use the science DOK levels on the previous pages to determine the DOK levels for the following five sample objectives. Except for the last, these objectives are for grade 8. When you are finished, turn the page to see whether you agree with the way we coded these objectives! Then try using the DOK levels on the 10 sample science items in Part ii.

Objective 1. Students should identify the structure and function of the major parts of animal and plant cells.

Objective 2. Students should design and conduct a science investigation in their home or community that involves data collection, display, and interpretation.

Objective 3. All students will analyze claims for their scientific merit and explain how scientists decide what constitutes scientific knowledge; show how science is related to other ways of knowing; show how science and technology affect our society; and show how people of diverse cultures have contributed to and influenced developments in science.

Objective 4. All students will measure and describe the things around us; explain what the world around us is made of; identify and describe forms of energy; and explain how electricity and magnetism interact with matter.

Objective 5. (Grade 10) Students should be able to explain the process of photosynthesis in detail.

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DOK Levels of the Sample Science Objectives

Objective 1. Level 1. "Identifying" the cell parts and their functions only involves recalling and naming/labeling.

Objective 2. Level 4. This requires extended time and involves all of the major aspects of a scientific investigation. If the most involved type of activity that a scientist ever engages in is not a Level 4 activity, then what is?

Objective 3. Level 3. The activities described in this objective require synthesis of different kinds of information, analysis of information, and criticism based on scientific methodology, and deep explanation.

Objective 4. Level 2. It is difficult to determine the DOK level for an objective with many parts like this. Measuring and identifying are typically Level 1 activities, but describing and explaining can signify different levels. With the exception of the last phrase of this objective, the descriptions and explanations asked for here are of *things* rather than *processes*, explanations of *what* rather than *how*. However, "explain how electricity and magnetism interact with matter" could call for some synthesis of different kinds of information, which would signify a higher level of knowledge. On the other hand, the explanation asked for here could be quite simple, too. So parts of this objective are Level 1 and parts are Level 2. What should we do? In such a case, you should code the objective according to the *highest* depth of knowledge that it requires the student to display, even if this DOK level is only found in one part of the objective.

Objective 5. Level 2. Students here not only must recall simple definitions and terms, but must also be able to describe and explain a process. On the other hand, this does not require any strategic reasoning, such as using the process of photosynthesis to make sense of an observed phenomenon.

Sample Science Assessment Items

Now try coding some sample assessment items using the science DOK levels. There are six items for grade 8 and four for high school. After you are finished coding these, read our "answers" on the following page.

The following six items are from grade 8 assessments:

1)
Which group of organisms would all be found living in a tropical rain forest?

A) Lizards, insects, cacti, kangaroos
B) Vines, palm trees, tree frogs, monkeys
C) Evergreens, moose, weasels, mink
D) Lichens, mosses, caribou, polar bears

2) Make a graph of your heart rate as you walk in place for five minutes.

3)[1]

The purpose of this task is to determine where, how high, and for what purpose (flood control, recreation, hydroelectric power, etc.) to build a dam. You will have a total of 45 minutes to complete this task. You may use up to 20 minutes to complete the group work, found on the first two pages of this form. When you finish the group activity, someone from your group should tell the facilitator. Then you may open this form and follow the directions inside by yourself.

Your group should have the following materials:

- Plastic model
- Clay
- Water in a pitcher
- Map
- Ruler
- Paper towels

Pencils (cont'd on next page)

GROUP ACTIVITY (cont'd from previous page)

1. Examine the model of the river valley as well as the map you have been provided. Using this information, discuss possible sites for a dam.

2. Use the clay to construct a dam on the model. With the water, test the impact of your dam on the nearby areas. Try different locations and dam heights based upon the dam's purpose. Record the different locations on the group's map. Record information from the trials in the chart on the next page.

Record information from your group's tests in this chart.

Site #	Location	Purpose	Impact

[1] [This item was contributed to the PALS (Performance Assessment Links in Science) website (http://www.ctl.sri.com/pals/) by the Kentucky Department of Education.]

Make sure that each group member's name appears on the map. One member of the group should insert the map into his or her response form when passing in the completed form.

When you are finished with the work on this page, one member of the group should tell the facilitator that your group has finished its group work. Then go on to the individual work. Remember that you must work alone on those pages. You may not discuss the questions or share information.

INDIVIDUAL ACTIVITY

3. After reviewing the work your group has done, where would you place the dam and how high would you make it? Why?

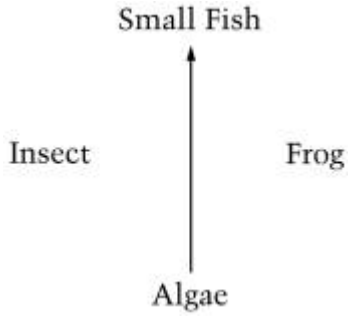
4. What social, environmental, and economic impacts would the location you chose for the dam have on the surrounding community?

5. Describe concerns you would include in an environmental impact statement for dam sites other than the one you selected in question 3.

Be sure one member of the group inserts the map inside his or her form for collection.

4) When operating, ordinary incandescent lightbulbs produce a lot of heat in addition to light. Fluorescent lightbulbs produce much less heat when operating. If you wanted to conserve electricity, which type of bulb should you use? Explain your answer.

5)
You will now finish a diagram of a food web in the pond. The food web shows what eats what in the pond system. Draw arrows in the diagram below from each living thing to the things that eat it. (The first arrow is drawn for you.)



6)
Suppose that a farmer near the pond sprayed crops with a pesticide to kill insects and that some of the spray washed into the pond. (This pesticide breaks down very slowly.) If several months later a biologist tested all the organisms in the pond system for the pesticide, which organism would most likely have the greatest concentration of the pesticide? Explain your answer.

The following six items are from High School assessments. The first two refer to this passage:

During the development of chemistry, many chemists attempted to explain the changes that occur when *combustible* (capable of burning) materials burn and metals corrode or rust. The following are two proposed theories.

Phlogiston Theory

According to this theory, combustible materials, such as wood, coal, or metal contain a massless "essence" or presence called phlogiston. When combustion occurs, the phlogiston is released from the combusting object and is absorbed by the air. For example, when a piece of wood is burned, phlogiston is released to the air and the wood is converted to ash. The ash is free of phlogiston and can no longer support combustion. Similarly, if a metal is heated, the phlogiston is lost to the air and the metal is converted into a nonmetallic, powdery substance called ash, or calx. The *corrosion* (changing of a substance by a chemical reaction) of metals, such as the rusting of iron (Fe), also involves the loss of phlogiston from the metal, but at a slower rate than burning. Rust can be turned back into metal by heating it in air with a substance rich in phlogiston, such as charcoal. A transfer of phlogiston from the charcoal to the rust converts the rust back to metal.

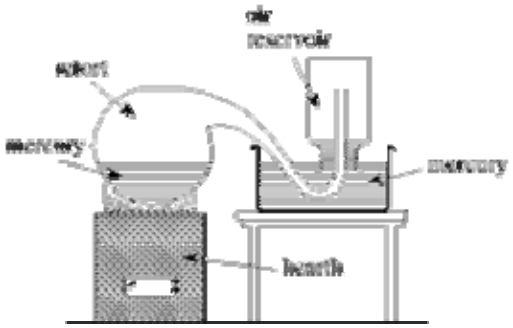
Oxygen Theory

According to this theory, burning and rusting involve an element called oxygen, which is found in the air. The complete combustion of a piece of wood involves the rapid reaction of the wood with oxygen gas (O_2) to produce carbon dioxide (CO_2), which is a nonflammable gas, and water (H_2O). The rusting of iron involves the slow reaction of iron with oxygen to produce iron oxides such as Fe_2O_3. These iron oxides are known as rust. Heating rust with charcoal produces iron because the charcoal combines with the oxygen in the rust. In these transformations, there is a *conservation of mass* (the total mass of the reactants must equal the total mass of the products in a chemical reaction). In these reactions matter is neither created nor destroyed, but merely transformed.

7) According to the Phlogiston Theory, the gases collected from the complete burning of a piece of charcoal in air would be capable of:

F. converting the ash from corroded tin back to tin metal.
G. supporting combustion of another piece of charcoal.
H. rusting iron.
J. converting wood ash into rust.

8) A chemist heated a sample of mercury for several days in the apparatus shown below. As the experiment proceeded, the mercury in the retort became covered with a red powder, and the volume of mercury increased in the air reservoir. The remaining material in the reservoir would not support combustion. Which of the following theories is supported by the results of this experiment?



A. The Phlogiston Theory, because the red powder resembled an ash
B. The Phlogiston Theory, because the air in the reservoir could not support combustion and therefore did not contain oxygen
C. The Oxygen Theory, because the mercury level dropped in the air reservoir indicating increased oxygen content
D. The Oxygen Theory, because the mercury level rose in the air reservoir indicating decreased oxygen content

The following sample high school assessment items do not use the above passages.

9) A scientist synthesizes a new drug. She wants to test its effectiveness in stopping the growth of cancerous tumors. She decides to conduct a series of experiments on laboratory mice to test her hypothesis.

What should she do?

a. Give half the mice the drug, the other half none, and compare their tumor rates.
b. Give the drug to all mice, but only to half every other day, and record tumor rates.
c. Double the dosage to all mice each day until tumors start to disappear.
d. Give the drug only to those mice who have tumors and record their weights.

10) The results of one of her experiments are shown in the table below:

Average tumor size in millimeters by dosage and days of treatment

	Days of Treatment						
Dosage	**1**	7	**14**	**21**	**28**	**35**	**42**
150mg	5	6	8	11	13	15	18
300mg	5	5	6	7	7	9	10
600mg	5	5	4	4	5	4	3

What can she conclude from these results?

a. The effectiveness of the drug over time depends on the size of the dosage.
b. The drug is effective over time regardless of the size of the dosage.
c. The size of the dosage affects tumor size regardless of the length of time.
d. The drug is ineffective regardless of the dosage or length of time.

11) What is the process called which plants use to manufacture sugar from sunlight?

12) In a laboratory experiment using spectrophotometry, an enzyme is combined with its substrate at time zero. The absorbance of the resulting solution is measured at five-minute intervals. In this procedure, an increase is absorbance is related to the amount of product formed during the reaction. The experiment is conducted using three preparations as show in the table below.

	Absorbance				
Enzyme preparation	**0 min**	**5 min**	**10 min**	**15 min**	**20 min**
I. 3 mL enzyme, 2 mL substrate, pH 5	0.0	0.22	0.33	0.38	0.37
II. 3 mL boiled enzyme, 2 mL substrate, pH 5	0.0	0.06	0.04	0.03	0.04
III. 3 mL enzyme, 2 mL substrate, pH 6	0.0	0.32	0.37	0.36	0.38

The most likely reason for the failure of the absorbance to increase significantly after 10 minutes in preparation III is that

a. the reaction is thermodynamically impossible at pH 6
b. the enzyme is not active at this pH
c. a pH of 6 prevents color development beyond an absorbance of 0.38
d. the enzyme is degraded more rapidly at pH 6 than it is at pH 5
e. most of the substrate was digested during the first 10 minutes

DOK Levels for the Science Sample Assessment Items

Grade 8 Items:

1) Level 1. This item assesses "the recall of information such as a fact or definition."

2) Level 2. This item has several steps and requires some decision making. Students must decide appropriate intervals for measuring pulse and procedures for graphing data. "Level 2 activities include making observations and collecting data; classifying, organizing, and comparing data; and organizing and displaying data in tables, graphs, and charts."

3) Level 4. An example in the Level 4 definition is "Conduct an investigation, from specifying a problem to designing and carrying out an experiment, to analyzing its data and forming conclusions." This item requires students to perform the breadth of activities an actual scientist would perform and demands extended time and thought.

4) Level 3. If this did not require an explanation, it would be Level 1. But here students must explain the complex connection between electrical consumption and production of heat in order receive full credit. "In most instances, requiring students to explain their thinking is at Level 3."

5) Level 1. Even though this item has multiple steps, the steps are not interrelated and do not increase the item's cognitive demands. Each step involves only recall.

6) Level 3. Explaining a simple and short answer can be Level 2, but the explanation required here is much more involved. The rubric requires giving full credit only if the student response "names the highest animal on the food chain, the heron, as having the greatest concentration of the pesticide." In addition, the response must demonstrate an understanding of biological magnification by explaining that the heron accumulates the greatest concentration of the pesticide from the fish it eats because the fish have accumulated the pesticides from the organisms they have eaten."

High School Items:

7) Level 3. Although it is uncommon, it is possible for a multiple choice item to be at Level 3. This item employs demanding reasoning, because it requires the student to make a complex inference based on an unfamiliar theory.

8) Level 3. Like the previous item, this involves making complex inferences from two conflicting theories. This non-routine problem also requires "drawing conclusions from observations" and "explaining phenomena in terms of concepts."

9) Level 2. Students must at least apply knowledge of controlled-experiment design to this situation, or derive it from the choices offered.

10) Level 2. If this item was open-ended, asking what conclusions could be drawn from the data and why, then it would be Level 3. Here the student only needs to check which of the presented solutions is most reasonable, which requires no decision-making or creativity.

11) Level 1.

12) Level 3. This is another example of a multiple-choice item that is still Level 3, this time due to the complexity of the presented situation. Students must compare the interaction of two dependent variables and interpret the data in light of a complex body of interrelated concepts.