Biology in Science--A Process Approach

● Edwin B. Kurtz, Jr., American Association for the Advancement of Science, 1515 Massachusetts Avenue, N. W., Washington, D. C. 20005

Another curriculum study for elementary pupils, written for teachers, is described here. The author is also Professor of Botany at the University of Arizona.

Science—A Process Approach (Commission on Science Education, 1965-66) is a science curriculum for children in kindergarten (K) through grade 6. This curriculum is sponsored by the Commission on Science Education of the American Association for the Advancement of Science, and is supported by funds from the National Science Foundation. Materials for K to grade 3 have been tested for three years in over 150 classrooms in 16 cities across the nation. Material for grades 4 and 5 is now in the third year of tryout, and material for grade 6 is in the second year of tryout (Commission on Science Education, 1966).

The outstanding characteristic of *Science—A Process Approach* is that children learn how to do what scientists do (behaviors). Thus, the facts and concepts discovered by scientists provide only the vehicle for this behaviorally based curriculum and are not the goal of the instruction. Other unique features crucial to understanding the place of biology in the program are:

1. The published materials are for the teacher; there are no texts for children.
2. The instructional objectives are precise descriptions of behaviors the child is to demonstrate at the completion of each exercise; the goals of the instruction are *not* stated in terms of the subject matter the teacher will present to the children.
3. The behavioral objectives are grouped into fourteen processes of science: observing, classifying, measuring, communicating, using space/time relations, using numbers, predicting, inferring, formulating hypotheses, controlling variables, defining operationally, interpreting data, experimenting, and formulating models; the first eight processes are emphasized in K to grade 3 and the last six are emphasized in grades 4, 5, and 6 (Fig. 1).
4. The behavioral objectives comprising each process are arranged in a hierarchy and each objective in this sequence requires the learning of the previous behaviors (Gagné, 1965a and 1966; Livermore, 1964; Walbesser, 1965 and 1966); biological or other science facts

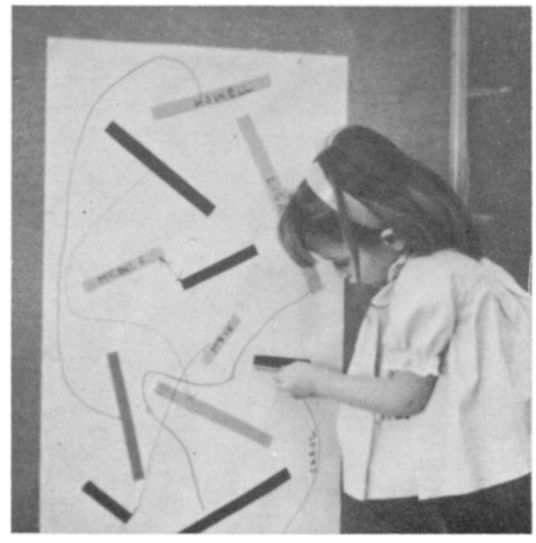

Fig. 1. Child measuring by comparing lengths.

Table 1. A classification of biological exercises by both science process and grade level. The number of all exercises at each grade level is in parentheses. These data will change slightly as the material is tested in classrooms and revised.

Part Number	Probable Grade Level	Number of Biological Exercises per Science Process[1]													Total Number of Exercises
		Obs	Cl	S/T	Comm	Meas	Pred	Num	Inf	ID	CV	DO	FH	FM	Exp	
1	K	2	2													4 (22)
2	1	3	2	2	2	2										11 (26)
3	2	1	1		3	2	1									8 (23)
4	3	2	1						2							5 (23)
5	4								1	4	4	1				10 (26)
6	5							1		2	6	1	3			13 (24)
7	6									2	1		1	4	3	11 (22)
1-7	K-6	8	6	2	5	4	1	1	3	8	11	2	4	4	3	62 (166)

[1] Abbreviations used in this table and also Table 2 are: Obs, Observing; Cl, Classifying; S/T, Using Space/Time Relations; Comm, Communicating; Meas, Measuring; Pred, Predicting; Num, Using Numbers; Inf, Inferring; ID, Interpreting Data; CV, Controlling Variables; DO, Defining Operationally; FH, Formulating Hypotheses; FM, Formulating Models; Exp, Experimenting.

and concepts are *not* the basis for the structure of this science curriculum.

5. The books for teachers consist of sets of exercises arranged in the sequence prescribed by the behavioral hierarchy; each exercise specifies the behavioral objectives the children should acquire.

6. Each exercise consists of statements of the objectives, rationale, materials, instructional activities which involve each child in performing science skills, and an appraisal activity used by the teacher to determine whether the specified behaviors have been acquired by the children.

7. In the tryout program, at the conclusion of each exercise a competency measure is administered individually to three children selected at random in each classroom; this measure requires the child to demonstrate the desired behaviors in a context not duplicating that used in the instructional activities.

8. Revision of the exercises is based on children's scores on the competency measures and information from teachers in the tryout program; an exercise is considered acceptable when 90% of the children tested can perform 90% of the tasks on the competency measure for that exercise.

9. An education program for teachers has been prepared on the same basis, including statements of behavioral objectives for teacher education, involvement of teachers in the instructional activities, and assessment of their acquisition of behaviors.

10. The process, Using Numbers, provides instruction in mathematical skills required for specific science exercises, particularly those in Measuring, Using Space/Time Relations, and Interpreting Data.

11. Other features are: use of the metric system of units and degrees Celsius rather than degrees Fahrenheit; distinction between mass and weight; and inclusion of exercises from the behavioral science (optical illusions, learning and forgetting, competition and cooperation, reaction time).

One way to analyze the biology in *Science —A Process Approach* is to identify the exercises of a biological nature which have behavioral objectives belonging to each of the fourteen science processes (Table 1). Biology is represented in all processes, and 37% of the 166 exercises for K to grade 6 use biology as the vehicle for instruction. There are many other exercises which provide experiences for the child in related areas: observing solids changing to liquids; observing the weather; observing sound, color, odor, taste, texture; classifying solids, liquids, and gases; measuring length, area, volume, weight, mass, temperature, speed, rate of change, force.

A detailed description of the biology in this science curriculum requires specification of the behavioral objectives and the

Table 2. Summary of the behavioral objectives and context for some of the exercises of a biological nature in Parts 1 to 5.

Number of exercise in each Part and science process	What the child should be able to do at the end of the instruction of each exercise	Biological context of the exercise
	Part 1 (for Kindergarten)	
3-Obs	Identify an object and construct groups of objects on the basis of color, shape, texture, and size.	Assortment of apples, bananas, peaches, grapes, nuts.
4-C1	Construct one-stage classifications of objects using characteristics selected by himself or someone else; state the criteria used for the classification.	Sets of leaves, nuts, and mono- and bivalve shells.
	Part 2 (for Grade One)	
2-S/T	Identify, name, and demonstrate symmetry of objects; state and demonstrate that some objects can be folded or cut in more than one way to produce matching halves.	Common edible fruits and vegetables.
8-Comm	Name properties of an object (color, length, shape, symmetry, texture, odor, and so on) so a second person can identify the object.	Pictures of animals.
	Part 3 (for Grade Two)	
12-Meas	Estimate linear dimensions of objects in centimeters, decimeters, or meters; observe an object of a known length or width and name a familiar object which is approximately the same length or width.	Children determine if a 20-meter long *Brontosaurus* or a 6-meter high *Tyrannosaurus* would fit in their classroom; lengths of children's pets are compared with objects in the classroom.
23-Pred	Demonstrate a method for collection and organization of data; construct a bar graph from the data; state a prediction based on the data in the graph; state how the prediction could be tested.	Survey of children's preferences (favorite animal, favorite flavor of ice cream); predictions about preferences of other children.

	Part 4 (for Grade Three)	
4-Inf	Distinguish between an observation and an inference; construct inferences from available evidence of relationships between animal tracks and characteristics or the environment in which the animal lives; demonstrate that inferences may be altered by additional observations.	Pictures of outlines of animal feet, bird beaks, and bird claws; broken nuts and acorns; logs of wood with animal borings; remains of animal homes (nests, cocoons); animal tracks in nature.
9-Obs	Identify stimuli in the environment of an animal; identify responses of an animal to a stimulus.	Responses of themselves, fish, and a turtle to various stimuli.
	Part 5 (for Grade Four)	
1-ID	Describe changes in the performance of an animal that indicate learning has taken place; construct a graph showing changes over a period of time.	Guinea pigs and a maze.
2-CV	Identify variables in an activity in which water moves within materials; identify variables which are manipulated or are held constant; state and demonstrate that water moves upward in some materials faster than in others; identify materials which have greater water-holding power than others.	Seeds imbibing water; soil; fabric.
12b-ID	Name a property to be measured as a means of describing variations in a population; demonstrate a procedure for measuring the property and for ordering groups of measurements; construct a graph of the frequency distribution of the measurements; state and apply a rule for finding the mode, median, mean, and range of a set of data, and identify each of these numbers on the graph.	Variation in pea pods and icicle radish plants.
14-DO	Identify, using a microscope, the small units of varying size and shape that make up living things; draw representations of these units; construct an operational definition of a cell in descriptive terms.	Cells of onion, lettuce, tomato, cucumber, celery, apple, and elodea.

biological context within which the child acquires the behaviors (Table 2). By relating the biological context used to the behavioral objectives of the exercise, one may picture what the child will be doing in the classroom. The behaviors which a child must have acquired previously in order to learn the behaviors of each exercise in Table 2 are specified in the hierarchy for each science process. A suggestion of these relationships is provided by the position of each exercise of a biological nature in the set of exercises for each grade.

Although the books for grades 5 and 6 of the 1966-67 experimental edition are still in preparation, it is apparent that the fifth and sixth grade child will have ample opportunity to work at a sophisticated level with biological materials in this science curriculum.

Most biology courses in the past were factually and conceptually oriented. Hence, it should appear unusual to have a science curriculum described in terms of student behavior and not in terms of facts and concepts to be told by the teacher. Yet for many reasons (Gagné, 1965b; Walbesser, 1965), this kind of curriculum design has much to offer. Indeed, this approach to curriculum design should also find application at the secondary and college levels (Kurtz, 1965; Walbesser, 1966).

Literature Cited

Commission on Science Education. 1965-66. Science—A Process Approach. Third Experimental Edition (1965-66) and Revision (1966), Parts 1 to 7, Commentary for Teachers, Competency Measures for Parts 1 to 7, and Process Measure. Am. Assoc. Adv. Sci., Washington, D.C.

—1966. Newsletter 2 (4) May. (This and other issues of the *Newsletter* may be obtained free by writing Am. Assoc. Adv. Sci., Washington, D.C.)

Gagné, R. M. 1965a. The psychological bases of Science—A Process Approach. Am. Assoc. Adv. Sci., Washington, D.C. Misc. Publ. 65-8. 35 pp.

—1965b. The conditions of learning. Holt, Rinehart and Winston, Inc., New York. 308 pp.

—1966. Elementary science: a new scheme of instruction. Science *151* (3706): 49-53.

Kurtz, E. B. Jr. 1965. Help stamp out nonbehavioral objectives. Science Teacher *32* (1):31-32.

Livermore, A. H. 1964. The process approach of the AAAS Commission on Science Education. J. Res. Sci. Teaching *2* (3):271-282.

Walbesser, H. H. 1963. Curriculum evaluation by means of behavioral objectives. J. Res. Sci. Teaching *1* (4):296-301.

—1965. An evaluation model and its application. Am. Assoc. Adv. Sci., Washington, D.C. Misc. Publ. 65-9. 99 pp.

—1966. Science curriculum evaluation: observations on a position. Science Teacher 33 (2):34-39.

Summer Institute for College Teachers of Biology

A summer institute for junior and undergraduate college teachers of biology, supported by NSF, will be held in the Thompson Biological Laboratory of Williams College between June 26 and August 6, 1967. Fifty participants will study a common program designed to explore in some depth recent advances in three areas of biology: Development, Behavior, and Ecology. Lecture, discussion, and laboratory programs will be presented by a staff of fourteen biologists, together with a number of special lecturers. Opportunity will be provided for informal discussion of the organization and content of the introductory biology course, "core" curriculum, position of organismic biology, self-education, teacher training and updating, MPh and AD degrees, science for the nonmajor, problems faced by transfer students, BSCS programs, etc.

No tuition or fees will be charged, nor will any credit or degree be given. Information and application forms may be obtained from Prof. Allyn J. Waterman, Department of Biology, Williams College, Williamstown, Mass. 01267. All applications postmarked by February 15th will be considered together, later ones individually.