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Scope of Study: The high school biology course is a comparatively new subject, having originated slightly over a half century ago. Within this space of time many changes have occurred in the subject and most of these developments point toward what is commonly known as functional biology. This report traces part of this development by a comparison of some of the first textbooks in the subject with their more modern counterparts. But the emphasis of the report centers upon the current subject as related to a high school biology teacher when the objectives, content, sequence, methods and evaluation are discussed. Materials used are chiefly (1) modern and older textbooks, (2) professional literature, (3) course outlines.

Findings and Conclusions: Trends in biology teaching indicate that the subject has become more practical and less technical, with increased emphasis upon the function of science in developing understanding of major principles and attitudes. Although there is general agreement upon the broad objectives, considerable variation is evident in relation to content, sequence, methods and evaluation of the course. The content of the course, as presented by modern high school text books, seems to be in general accord with the areas emphasized by teachers. The sequence of the areas comprising the content remains a controversial subject. The decision of arrangement of the sequence is commonly left to the discretion of the individual instructor and can be varied in accordance with local situations. Methods of presentation represent perhaps the greatest variation with the emphasis upon the teachers' ingenuity and initiative. Trends in evaluation, typical of the basic changes in the field, indicate an enlargement of the scope from examinations which reveal how much subject matter the student retains to an appraisal of total pupil growth.

ADVISER'S APPROVAL ______________________

THE DEVELOPMENT OF FUNCTIONAL BIOLOGY

By

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1951

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CHAPTER I

INTRODUCTION

One of the most often repeated words in educational circles today is "functional" -- functional classes, functional subjects and functional education. Every conscientious teacher is striving to make his classes more functional. Though any competent teacher could satisfactorily define the term and quote innumerable examples, there is a question as to how many are victims of previous educational classes in which profound and glowing phrases were projected, the students became glib in quoting authors and experts, and the instructors so adept in generalizing that worthwhile objectives were lost in a quagmire of misunderstanding.

Nevertheless, since functional education is one of the prime objectives of our modern public school system, it behooves each teacher to become acquainted with the functional aspects within his own field. With this object in mind, the following questions naturally arise:

Just how did functional biology evolve and what are the generally accepted objectives? What are the topics or areas included in the content, and which sequence is considered preferable? What are some of the practical methods that can be employed in the classroom and how can their effectiveness be evaluated?

A general survey of the literature in the field indicates that the major task involved in this report will be that of selecting appropriate material so as to evade generalizations common in much educational material and to omit certain details in which the author is personally interested.

A comparison of modern textbooks with those written near the turn of the century should clearly depict many of the changes that have occurred in the field, while a survey of the more recent books should certainly indicate the topics of which the course content is composed. An examination of professional literature reveals a wealth of practical classroom activities that have been successfully employed by experienced teachers in classroom situations. Course outlines and pamphlets of various kinds are available for reference if a diligent search is made. Discussions with classmates who are interested in the field of biology have also led to materials which will be included herein.

The expected values or outcomes of this report are selfish in nature. This opportunity is being seized to scrutinize and evaluate objectively the biology course before plunging into another year of teaching; to learn new methods and techniques of presenting subject material; to keep abreast with modern trends in a rapidly changing field; to be able to more fully utilize the knowledge gained during a year of intensive study; to become acquainted with textbooks to such an extent as to be capable of making an intelligent choice in this respect; and to improve the writer's scope and understanding of the subject of functional biology.

CHAPTER II

EVOLUTION

Prior to 1918 the objectives of science instruction were limited quite generally to emphasis of facts,[1] but a close examination of old biology textbooks will reveal indications of evolving functional biology previous to 1900. For example, T. H. Huxley, in revising his textbook,[2] stated in the preface:

> "No doubt there is much to be said for the principle of this arrangement, which leads the student from the study of simple to that of complex phenomena; but the experience of the lecture room and the laboratory taught me that philosophical as it might be in theory, it had defects in practice.....After two or three years' trial of the road from the simple to the complex, I became so thoroughly convinced that the way from the known to the unknown was easier for the student, that I reversed my course, and began with such animals as a rabbit or a frog, about which everybody knows something, while their anatomy and physiology is illustrated by innumerable analogies with those of our own bodies."

Although Professor Huxley was a very loquacious gentleman, his foresight was no greater than some of his contemporaries, for there was another movement during this same period which would be quite acceptable to the principles of functional biology. This was the promotion of the course as a study of natural objects and phenomena rather than a study of books.[3]

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[1]P. E. Smith, <u>Teachers' Manual for Our Environment Its Relation to Us</u> (Boston, 1953), p. 1.

[2]T. H. Huxley, <u>Practical Biology</u> (2d. ed., London, 1892), p. v.

[3]E. R. Boyer, <u>Elementary Biology</u> (Boston, 1898), p. iii.

A recent textbook in general biology, when compared with one of fifty years ago, would be recognizable at fifty paces. The general appearance of the modern text with its attractive colors and illustrated cover would make a strong appeal to any student, whereas the colorless and ill-proportioned older book creates an undesirable impression.

Within the covers of the books the variation is even more pronounced. A simultaneous examination of the two types will disclose considerable variation in the spacing and size of type used in their printing, along with supplementary conveniences such as paragraph headings in bold type, italics, etc. The physical part of reading the later books is made easier. Illustrations, graphs, charts and tables are entirely omitted by many of the earlier authors, and when included are usually of an inferior quality with reference to clarity and attractiveness,[4] whereas with the great number of textbooks competing in today's increased market[5] one might justly criticize the inclusion of attractive illustrations which serve no distinct purpose other than to make the text more alluring to undiscerning or inexperienced teachers.

However, one must admit that illustrations and charts have reached a very high level with the competition between publishers today. For example, one textbook has a copyrighted chart called "The Human Torso as Seen by the Trans-Vision Process,"[6] which artistically displays the front and back view of the same organs on transparent cellophane sheets which

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[4]H. G. Wells, Textbook of Biology (London, 1892), pp. 1-149.

[5]Kenneth E. Brown, Offerings and Enrollments in Science and Mathematics in Public High Schools, U. S. Education and Welfare Pub. No. 118 (Washington, 1956), p. 4.

[6]T. S. Moon, P. B. Munn and J. H. Otto, Modern Biology (New York, 1956), pp. 271-75.

are attached so that they can be superimposed against either the dorsal or ventral portions of the thoracic and abdominal cavities. This beautiful piece of work, along with other distinguishing features, has made this book one of the most popular, but the very latest edition has added a "Trans-Vision Process" for a chart of the internal and external anatomy of a frog, as well as a more attractive cover.

Perhaps the most important change in textbooks is that of subject material. In addition to more technical material, the older text will contain fragments of botany and zoology. In fact, some of them, as if in fear of slighting either field, evenly divide the contents into botany and zoology. Many of these served the function of laboratory guides with each topic separated into materials required, habitat, external anatomy and internal anatomy, with detailed and explicit instructions as to the methods of examination, types of notes, sketches, etc.

In contrast, a glance at the material presented to a biology class today will disclose such units as "How to Protect Our Bodies from Disease," or "Biology for Vocations and Hobbies." A person who is not well versed in modern educational philosophy might justly assume that the subject has become "diluted."

CHAPTER III

OBJECTIVES

In order to appreciate the newer trends in biology teaching, a person must become acquainted with the objectives of science instruction evolved in the last half-century or so. Since 1918 science yearbooks and similar reports have all emphasized the unique function of science in developing understandings of major generalizations or principles and scientific attitudes. The objectives have been stated by various writers in many different terms. Some prefer to divide them into numerous statements, others to condense them. Here they will be summarized as the generally accepted objectives of science instruction.[1]

First, there is knowledge. Despite all of the criticism by modern education, the acquisition of information must remain a primary aim of all education.[2] There is no denying that knowledge of facts is the foundation of understanding, the material with which habits of thinking and attitude are built, the substance from which principles are induced. That which is untenable, therefore, is the allowing of this objective to be the dominant, almost sole objective.

Next are generalizations, the principals, or "big ideas" of science. The biology of the classroom begins really to function in the student's

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[1] Smith, p. 3.

[2] D. F. Miller and G. W. Blaydes, Methods and Materials for Teaching Biological Sciences (New York, 1938), p. 15.

life when first he is able to generalize effectively on the basis of learned facts and to apply these generalizations to the conduct of his daily activities.

Thirdly, is listed "attitudes." Actually this might be more correctly listed "attitudes about attitudes." That is, almost any discussion about objectives in a science class, and biology in particular, will include considerable material pertaining to the importance of using suspended judgment and open-mindedness in forming attitudes.

The last of the generally accepted objectives this writer will list is "skills." Frankly, it requires a bit of imagination for this heading to encompass such varied objectives as the ability to read scientific content; to appreciate the contributions of scientists, of cause and effect relationships, of the effort involved in the search for truth. However, as stated in the introduction to this chapter, the object of this portion of the report is to summarize the generally accepted objectives and not to become involved in the innumerable objectives proposed by various educational leaders. Therefore, considerable "lumping" is necessary. In all likelihood, the skill most often mentioned is the use of the scientific method.

CHAPTER IV

CONTENT

Although most modern textbooks in biology agree upon the general objectives, their unit headings and methods of presentation are quite variable, and unless some method is devised by which they can be evaluated, any comparison of their content would become confusing. This confusion is compounded by the many textbooks in the field and the great variety in sequence even though the material is basically similar.

After much floundering in a sea of material, the following topics were chosen as typical and comprehensible:

1. Introduction (scientific method, hobbies, vocations, etc.)
2. Insects
3. Cells (the basis of life, etc.)
4. Animal biology
5. Human biology (psychology, physiology, diseases, etc.)
6. Health (physical and mental)
7. Heredity
8. Conservation
9. Life of past and present (evolution, ecology, etc.)
10. Plant biology

From a casual glance at the topics, it is obvious that many of them overlap and a distinct separation of some would be difficult and beyond the scope of this report. But after examining many textbooks and courses of study with reference to the above topics, the writer feels that it does represent the material found in recently published texts.

When various books are closely scrutinized with the object of listing the number of pages devoted to each topic, one is often caught in the position of putting a square peg in a round hole. For example, would you list diseases under Health or under Human Biology? Common sense and logic might indicate the former, but common usage by textbooks dictates the decision in favor of the latter.

Following is a table prepared using five textbooks in common use today:

TABLE I

THE CONTENT OF HIGH SCHOOL BIOLOGY TEXTBOOKS

TOPICS	PAGES DEVOTED TO EACH TOPIC TEXT 1	TEXT 2	TEXT 3	TEXT 4	TEXT 5	TOTAL	AVERAGE	RANK
INTRODUCTION, SCIENTIFIC METHOD, VOCATION AND HOBBIES	47	13	23	20	13	116	23	8
INSECTS	48	26	23	7	10	114	23	8
CELLS, THE BASIS OF LIFE	22	22	23	40	25	132	26	7
ANIMAL BIOLOGY	57	129	41	53	71	351	70	3
HUMAN BIOLOGY, PSYCHOLOGY, PHYSIOLOGY, DISEASES	100	128	122	100	98	548	110	1
HEALTH, PHYSICAL AND MENTAL	40	10	11	24	83	168	34	6
HEREDITY	32	35	22	40	45	174	35	5
CONSERVATION	40	32	30	2	10	114	23	8
LIFE OF PAST AND PRESENT, EVOLUTION, ECOLOGY	40	23	50	71	31	215	43	4
PLANT BIOLOGY	133	117	52	36	57	395	79	2

(Cont.)

TEXTS USED IN THE PREPARATION OF THIS TABLE:

Text 1: B. B. Vance and D. F. Miller, Biology for You (Chicago, Philadelphia, New York, 1954), pp. 1-652.

Text 2: T. S. Moon, P. B. Munn and J. H. Otto, Modern Biology (New York, 1956), pp. 1-757.

Text 3: G. W. Hunter and F. R. Hunter, Biology in Our Lives (New York, 1955), pp. 1-534.

Text 4: F. M. Wheat and E. T. Fitzpatrick, Biology (New York, 1955), pp. 1-571.

Text 5: E. Kroeber and W. H. Wolff, Adventures with Plants and Animals (Boston, 1950), pp. 1-616.

After a general idea of the content of textbooks is known, the question naturally arises as to whether or not these topics are the ones actually emphasized by the teachers. An examination of the literature concerning this subject reveals a study of instruction in general biology in a representative sampling of the public schools of the country by the Office of Education, Federal Security Agency.[1] Following is a table based on that study:

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[1] G. F. Cole, "The Present Status of Instruction in General Biology," The American Biology Teacher, XIII (1951) 153.

TABLE II

TOPICS EMPHASIZED IN GENERAL BIOLOGY

AREAS (TOPICS) EMPHASIZED	TOTAL SCHOOLS REPORTING		RANGE OF INSTRUCTIONAL TIME IN DAYS			RANK
	NO.	PERCENT	MIN.	MAX.	AVERAGE	
Schools reporting areas	93	100	..	..	..	..
Genetics, Heredity & Race	79	84	5	50	17.7	11
Conservation	77	82.5	5	90	82.6	10
Health	71	76.5	10	120	36.5	3
Classification	61	65.5	2	95	28.2	6
Human Biology	37	39.9	10	45	31.0	4
Plant Biology	30	32.4	15	90	37.0	2
Animal Biology	23	24.8	15	90	42.5	1
Reproduction	22	23.6	3	40	21.5	7
Behavior (Psychology)	24	25.8	8	45	18.9	8
Food and Nutrition	17	18.3	3	46	28.6	5
Disease Control	15	16.25	3	40	18.9	8
Adaptation and Evolution	8	8.5	5	20	13.5	12
Ecology	5	5.4	12	30	17.4	13

CHAPTER V

SEQUENCE

The traditional manner of arranging the subject matter of a text or course of study in the phylogenetic sequence was so widely adopted that it still persists. This logical arrangement appeals to the mind of the taxonomist and evolutionist and can be used with some advantage in more highly specialized classes.[1] A movement was begun previous to the turn of the century by T. H. Huxley to replace this sequence with the more functional approach of proceeding from the known to the unknown, and one of the most popular bases for selecting the order of the topics today depends upon the availability of materials in local situations.[2]

Since logical reasons and criticisms exist for each of the methods, the writer agrees with the widely held opinion that the answer lies in the nature of a compromise -- if the objectives of functional biology are to be realized, there seems to be no other way.

Most textbooks are prepared in such a manner that the sequence of units can easily be modified as needed, to suit the demands of various courses. Therefore, so as to conform with the writer's own philosophy of education, liberties have been taken in arranging the topics in the following order:

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[1]Miller and Blaydes, p. 34.

[2]Ibid.

(1) Introduction, Scientific Method, Vocation and Hobbies
(2) Insects
(3) Cells, the Basis of Life
(4) Animal Biology
(5) Human Biology, Psychology, Physiology, Diseases
(6) Health, Physical and Mental
(7) Heredity
(8) Conservation
(9) Life of Past and Present, Evolution, Ecology
(10) Plant Biology

Perhaps the stress on the importance of teaching by the use of taxonomic keys as set out by Dr. Edmund W. Sinnott in his lecture, "The Importance of Biology in a Liberal Education," March 21, 1957 at the Oklahoma A & M College Classroom Building, best explains the reasons for this sequence.

Since most plants flower in the spring, and plant taxonomy is based upon floral structures, the position of plant biology in the sequence becomes obvious. When the latter part of the school year is devoted to the study of plants, this automatically arranges the sequence of the study of insects, which are uniquely fitted for taxonomic study at high school level, at or near the beginning of the fall term. The remaining topics are arranged in conformity with the common sequence in modern texts.

CHAPTER VI

METHODS

Simultaneous with the change of sequence and an enlargement of the areas in the content of biology, and as an indication of the development of modern objectives, was the change from the old "assign-study-recite" method of teaching to the more recent practice of including various learning activities. An extensive examination seems to reveal almost as many methods as there are teachers. But a more intensive search will disclose that practically all of the newer methods or techniques hinge upon a single idea.

A current television program entitled "Youth Wants to Know" is enjoying considerable popularity, due in all probability to the seriousness displayed by the young people. This seriousness is nothing new to teachers. In fact, the very basis of functional education is to harness this "wanting to know" by introducing into the classroom concrete experiences, participation in learning activities and problem solving.

As a teacher of only a few years experience, the writer is acquainted with this tremendous motivating power. However, the problem is just what methods can be adapted to classroom procedure that will effectively incorporate this principle. An answer to this question can come from only one source: active classroom teachers in the field of biology. Therefore, material gathered from professional journals, experienced teachers in the National Science Foundation scholarship group, and textbooks that include articles by practicing biology teachers will be used as a solution. In order to effectively list some of these procedures, the intention is not to plan an entire course of study or to complete a detailed group of study plans, for any experienced biology teacher realizes the futility involved in such work. Rather the method will be to choose as examples some typical procedures and techniques successfully employed by others.

Taxonomic Keys

A search through course outlines will reveal the following list of learning activities: class trips, committees, debates, demonstrations, experiments, group discussions, interviews, investigations, problems, projects, pupil planning, etc. Taxonomic keys can be utilized to correlate most, if not all, of the foregoing activities.

The writer does not propose to subject high school students to material that many college students are unable to competently acquire, but rather agrees with the theory that a well prepared biology teacher, with sufficient material, can use "home made" keys to good advantage.[1] With this intent "The Golden Nature Series Guides" have been purchased. These books are an introduction to the world of nature, presenting those things which are most common and most easily seen. This guide includes birds, flowers, insects, mammals, reptiles and amphibians, and trees. They were written by an outstanding authority on science education -- Dr. Herbert S. Zim, University of Illinois, in cooperation with a noted specialist. Identification is made easy by over one hundred full color paintings in each book. These are rendered mostly from life by an outstanding artist and have been checked, corrected and rechecked by

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[1]B. L. Berka, "Keys for Your Classroom," The American Biology Teacher, XVII (1955), 75-76.

specialists. In addition to the aforementioned series, four other books on a more advanced level (two of which are currently being used in classes in which the writer is enrolled) have been purchased for the writer's use in devising "home made" keys and possibly for the use of superior students.

Following is an example of "home made" keys which is particularly applicable to classroom study because it includes animals which are easy to collect and which do not present the ordinary problems of care and space inherent with larger animals:

SIMPLIFIED KEY TO SOME COMMON
FRESH WATER INVERTEBRATES[2]

Directions to the students:

1. This key is based on structures or behaviors of animals which you can see.

2. To use the key, choices must be made. You must determine whether the animal is like A or AA; then proceed to the next choice, B or BB.

3. The name underlined is a genus name.

4. A name in capital letters is an order name or a common name.

KEY

A Animal whose bodies are one cell. . . . . PROTOZOA

B Protozoa with special structures for locomotion; usually seen swimming rapidly through the water.

C Protozoa swimming by means of 1 to 4 long whiplike hairs (flagella); locomotion slow . . . . MASTIGOPHORA

D Body spindle shape; with chloroplasts; appears deep green in color; one flagellum . . . . Euglena

(Cont.)

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[2]E. A. Larson, "Revealed by the Microscope," The American Biology Teacher, XIV (1952), 206-208.

DD Body without chromatophores; a single flagellum, rigid except near tip; at tip, flagellum looks like a coiled spring . . . . Peranema

DDD Body without chromatophores; two flagella; cytoplasm yellowish, translucent; anterior end with a notch, from which the flagella extend . . . . Chilomonas

CC Protozoa swimming by means of hairs (cilia); locomotion very rapid . . . . INFUSORIA

E Cilia very fine, evenly distributed over body; arranged in long rows or in a band around body; animal swims in spiral rotations; locomotion smooth, never jerky

F Body bell-shaped or trumpet-shaped; cilia conspicuous in a band around edge of bell or trumpet; animal often attached to debris.

G Body bell-shaped with contractile stalk.

H Stalks with a single individual; animal often breaks from its stalk . . . . Vorticella

HH Stalks branching with several individuals . . . . . Corchesium

GG Body trumpet-shaped, often blue in color; cilia in longitudinal rows, and around edge of trumpet leading to mouth . . . . Stentor

FF Body not bell-shaped; cilia never in a band but evenly distributed in longitudinal rows.

I Body slipper-shaped.

J Long groove in side of body leading to mouth . . . Paramecium

JJ Without groove in side of body; cytoplasm with vacuoles often filled with algae cells or filaments of algae . . . . Frontonia

II Body bean-shaped . . . . Colpoda

EE Cilia coarse, not evenly distributed but arranged in groups or "tufts" (cirri); these cirri used for walking as well as swimming; locomotion jerky.

K Body shovel-shaped, flattened, with large "V" leading to mouth; with stain, cell shows a nucleus in long "E" shape . . . . Euplotes

KK Body not shovel-shaped, more elliptical; two nuclei when stained . . . . Stylonychia

(Cont.)

EEE Body cilia reduced; central girdle of long bristle like cilia; locomotion by jumping . . . . <u>Halteria</u>

BB Protozoa moving slowly by creeping; no special structures for swimming; locomotion entirely by pseudopodia; often found in scum at top of jar . . . . SARCODINA

L Body assuming irregular shapes, no definite form; one nucleus when stained; protoplasm without covering . . . . . <u>Amoeba</u>

LL Body spherical, disc-like or doughnut-like; with shell like covering; two nuclei; usually brownish in color; pseudopodia seldom seen . . . . <u>Arcella</u>

LLL Body spherical, many radiating, spinelike rigid pseudopodia; cytoplasm highly vacuolated . . . . <u>Actinophrys</u>

AA Animals whose bodies are made up of many cells . . . . METAZOA

a Body wormlike; may or may not have a distinct exoskeleton or protective covering (cuticle).

b Body flat without external covering; not segmented.

c With eye spots.

d Body without pigment; usually creamy white. . . . . . <u>Dendrocoeleum</u>

dd Body with pigment spots; usually blocks, purple or gray . . . . <u>Euplanaria</u>

cc Without eyespots; body ciliated, usually with attached buds; ciliated pits present.

e Posterior end tapering to a sharp point . . . . <u>Stenostomum</u>

ee Posterior end blunt . . . . <u>Microstomum</u>

bb Body cylindrical, very transparent; cuticle present; internal organs visible.

f No distinct head, no segmentation, with transparent cuticle; a very active, threadlike worm . . . . NEMATODES

ff Head distinct; usually partially or completely segmented; swims or creeps . . . .

g Body with cilia; cylindrical or as a flattened cylinder.

h With two wheellike rotating ciliated coronas at anterior end around mouth; body very contractile, has adhesive toe or toes by which it attaches itself . . . . <u>Rotifera</u>

(Cont.)

hh Without rotating coronas at anterior end; body divided into distinct regions -- head, neck and body; dorsal surface covered with plates, hooks or bristles; bristles about the head and mouth; cilia on ventral surface; a graceful swimmer; easily confused with protozoa . . . . GASTROTRICHA

gg Body without cilia.

i Body segmented but not divided into distinct regions; segments equipped with setae (bristles). . . ANNELIDA

j With gill-like respiratory organ at posterior end.

k Respiratory organ with two long processes . . . . Aulophorus

kk Respiratory organ without long processes . . . . Dero

jj Without gill-like organ at posterior end.

l With bright ruby red, green or yellow droplets throughout the body . . . . Aeolosoma

ll With long, tubelike proboscis at anterior end . . Stylaria

ii Body segmented, always divided into distinct regions; air tubes or gills present; usually with three pairs of jointed appendages . . . . INSECT LARVAE

aa Bodies not wormlike; with a definite exoskeleton; with jointed appendages . . . . CRUSTACEA

n Body not visibly segmented.

o Body, head and feet completely enclosed in an opaque bi-valve shell; only those appendages used for swimming may be readily seen; oreal in outline . . . . . OSTRACODA

oo Body and feet only enclosed in a bi-valve transparent shell; head distinct; compound eyes and eye spots present; antenna always branched, usually featherlike. . CLADOCERA

p Antenna free (not covered), used for swimming.

q Head joined to body without any indentation . . . . . . Daphnia

qq Head joined to body with deep notched V-shaped indentation . . . . Ceriodaphnia

nn Body segments distinct.

r Head and thorax joined (cephalothorax), distinct from abdomen; many appendages . . .

s With antenna; many paired legs for swimming . . . . COPEPODA

(Contd.)

t Antennae short, not longer than cephalothorax; with 6-17 segments in each antenna; ruby red eye spots in center of head; body colorless . . . . . . <u>Cyclops</u>

tt Antenna long; as long or longer than body; with 23-25 segments; body reddish-orange color . . . . . . <u>Diaptomus</u>

ss Without antennae; four pairs of walking legs; abdomen globular; difficult to distinguish from the cephalothorax . . . . WATER MITES

rr Head, thorax, abdomen distinct; 3 pairs of appendages joined to thorax; with trachea (air tubes) and/or leaflike gills at the tip of abdomen . . . . INSECT LARVAE

Since the scientific method of thinking is one of the prime objectives of functional education and quite admittedly is a difficult principle to project, it seems appropriate to include in this chapter a concrete example that has been successfully presented to a high school biology class:[3]

1. The appreciation of the existence of a problem and a desire to solve it:

   A. Placing a microcosm in the classroom without comment.
   B. Wait until interest has reached its peak.
   C. Write questions on board.

2. The accumulation of facts and data which are pertinent to the problem.

   A. Class discussion in which the questions' order are are established and use analysis of the problem.

   B. Work broken up into parts by topics to provide for individual differences.

3. The formation of hypotheses as partial explanation, their testing, and their acceptance or rejection.

   A. Prepare a list of student hypotheses and have enough copies duplicated for each student.

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[3]Miller and Blaydes, pp. 16-22.

B. Direct the students to consider each statement on its merit and mark it: P - proved, D - disproved, or N - neither proved nor disproved.

4. Logical interpretation of data with an unwillingness to accept as proved any conclusion not supported by adequate valid evidence.

A. General discussion in which a student reads a statement and gives his reasons for marking it P, D, or N.

B. Let the students volunteer to perform outside experiments for concluding proof.

CHAPTER VII

EVALUATION

In functional biology the term "evaluation" is commonly encountered and has considerable significance. It is more meaningful than "test" or "examination."[1] The latter terms usually imply a method of discovering what the student has attained with respect to the standards set for him by the teacher, whereas "evaluation" is concerned with the all-around development of the learner. It is a means of appraising all aspects of total growth which indicate how much genuine learning is being achieved.

Judging the results of functional teaching is similar to a physician's diagnosis. He uses instruments for objective measurements. He secures subjective impressions by consultation. From these, he appraises his patient's health. The means which are being used in science education for comprehensive evaluation include the following examples.

Questionnaires and Check Lists[2]

Tests generally help determine what a student remembers. One of the best ways to find out how youth thinks, feels and acts is to ask the students themselves. A questionnaire provides an easily constructed instrument to this end. Pupils express themselves very frankly on

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[1]Miller and Blaydes, p. 68.

[2]*Course of Study in Science for Secondary Schools*, Department of Public Instruction Bulletin 400, Commonwealth of Pennsylvania, (Harrisburg, 1951), pp. 316-320.

questionnaires whether they sign them or not. The reliabilities exceed those of many tests. They can be constructed to measure any aspect of behavior and provide valid and interesting results both for student self-appraisal and for teacher information. They may be prepared to reveal attitudes, opinions and behaviors.

Check lists are also easily constructed. They provide for day-by-day student self-appraisal in the development of study habits, health behaviors, and other skills which are needed for living and learning.

Paper-Pencil Forms

(a) Improved essay-type examinations, (b) standardized tests, (c) homemade objective tests, (d) behavior rating scales, (e) check lists, (f) pupil logs or diaries on what was learned from day to day or on what contribution the pupil made to a class discussion or project, and (g) questionnaires on pupil needs.

Classroom Questioning and Discussion

This type of evaluation should indicate what problems the pupils have. Pupils may be asked to submit problems. Sub-grouping may be employed for study, discussions and reports. A simple check list, used by the teacher, will indicate after each student's name the degree and nature of his participation, perception, and committee leadership.

Laboratory Skills and Behaviors

A simple check list of pupils' names and desirable types of behavior is of great assistance in day-by-day evaluation. How a student attacks problems, gets down to work, arranges apparatus, keeps surroundings neat, works with others, uses reference material, weighs evidence, forms conclusions, and reports results are important criteria. Descriptive quantitative ratings or anecdotal recordings of what is actually observed may be used.

Individual Interviews

Here there is better opportunity to appraise students' needs, interests and attitudes than in either a quiz or a discussion. Rapport should be established which will lead the student to talk freely. Brief anecdotal records will be of value to the teachers whose satisfaction comes from helping to produce wholesome men and women as well as scientists. The ability to interview students in this manner can be gained by any teacher. Yet fifty four percent of the 5,000 students questioned in an inquiry on student needs stated that they do not feel free to talk with a teacher in their schools, and thirty six percent of a sampling of dropouts stated that they would have remained in school if any one teacher had been interested in them as individuals.[3]

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[3] Course of Study in Science for Secondary Schools, Department of Public Instruction Bulletin 400, Commonwealth of Pennsylvania, (Harrisburg, 1951), p. 319.

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