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Title of Study: DEVELOPING AN APPRECIATION OF SCIENTIFIC METHOD IN BIOLOGY

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Major Field: Natural Science

Scope and Method of Study: The purpose of this report has been to attempt to present an "ideal" method of teaching an appreciation of scientific method in biology. One of the difficulties in trying to reach tenable conclusions regarding the aims of science instruction in the modern school lies in the fact that, at present, we have difficulty in evaluating such statements made by educators and others. Research on whether an appreciation of the scientific method can be taught satisfactorily is cited and those techniques found to be successful by the author are presented in the form of an outline giving procedures for making a course outline in biology. Included at the end is a section containing a selected group of materials that might be used in teaching the scientific method and scientific attitudes.

Findings and Conclusions: For the teacher who recognizes each student as an unique personality, and who tries to teach his students as individuals, the problem of adapting the scientific method to best meet the needs of the individual becomes great and the obstacles to be overcome difficult. The teacher can, in a very general way, make at least a beginning by utilizing one or more of the following techniques:

1. Provide students with a simple explanation of the scientific approach and its uses, and provide an opportunity for each student to practice the techniques in simple ways.

2. Try to help students to make accurate observations, and group these observations into logical conclusions in a variety of situations and under a variety of conditions.

3. Try to develop in students the ability to see things in true perspective, and how to relate things to reality and practical living, that they may more effectively utilize their newly-gained knowledge of scientific procedures more advantageously.

4. Encourage use of the scientific method in solving problems encountered outside the classroom and in other classes.

ADVISER'S APPROVAL James H. Zant

DEVELOPING AN APPRECIATION OF SCIENTIFIC METHOD IN BIOLOGY

By

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Bachelor of Science

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DEVELOPING AN APPRECIATION OF SCIENTIFIC METHOD IN BIOLOGY

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PREFACE AND ACKNOWLEDGEMENT

The purpose of this report is to see how the developing of an appreciation of scientific method in biology can be accomplished. This can be accomplished through a better understanding of the student and those things that influence him. Using this knowledge, I hope to be able to instill in the student a high regard for scientific method and science in general.

Indebtedness is acknowledged to Dr. James H. Zant for his valuable guidance; to the members of the library staff who, without exception, have been notably pleasant and courteous in helping to find materials; and to the faculty members in the Life Science Department who always expressed willingness to help.

Indebtedness is also acknowledged to the National Science Foundation for making my stay at Oklahoma State University possible.

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PART I

INTRODUCTION

Statement of Problem

Most high school biology teachers, regardless of the approach, are interested in seeing that the students are aware of and appreciate what has been labeled as the scientific method. Many teachers, either through lack of training, time or facilities, discuss the problem solving approach with the students but give the student very little problem solving experience.

The purpose of this report is to see how the developing of an appreciation of scientific method in biology can be accomplished.

What about the question of developing an appreciation of scientific method in Biology? It is probable that the developing of an appreciation of this method at best will be a slow and laborious process and, at present, it seems doubtful that it can be brought about so completely and effectively that the student will comprehend its full meaning and applications. This seems partly due to the fact that the teacher's course must be feasible--it must be a compromise between what the teacher is expected to teach and what he would like to teach. Lack of time, overcrowded schoolrooms, lack of facilities, and other factors are partially responsible for this condition. The author is confident that the justification for the developing of an appreciation of this method lies

in the real practical values it contains for the students.

Since the large majority of high school students do not continue their formal education beyond the secondary level, it would seem logical to give them a usable technique which contributes to organized thinking and provides carry-over into many real life situations.

Scope and Limitations

Teachers of science have wholeheartedly accepted this truly significant objective: the student should know and be able to use the methods of science in the solution of problems. This acceptance, however, has not necessarily meant that anything constructive is being done in science classes to assure attainment of this objective by the students. Instead, there has been a feeling or a hope that the typical pattern of teaching and materials in science courses is sufficient to bring about the desired results.

However, just reading and talking about science will not effectively develop an appreciation of scientific method. Instead, students must be provided opportunities for recognizing problems and ways of solving them. The teacher must provide the motivation and guide the learning process in order to stimulate scientific thinking and to emphasize problem solving.

Purpose and Need

A beauty operator was trying to sell a customer an oil permanent. It would be much better, she thought. Oil is good for the hair. Gives it life.

"Well, I don't know," said the customer. "I should think it would be the worst thing to use with the waving fluid. I don't understand

chemistry, but I just thought they would go against each other, sort of. Wouldn't oil counteract the fluid?"

"Well, I don't know," replied the operator. "Maybe it would." Then, suddenly brightening, "I never thought about permanents that way, being chemical, that is. I had chemistry in school back home and I always got the highest mark they gave. I like it, but I've never connected it with anything outside of school."

"No," agreed the customer, "I don't really, either. It's pretty hard to see any connection."

"No," said the operator, "I guess there just isn't very much connection."[1]

Science has "dug" itself in as a significant part of everyone's education. True enough, the graduate has taken science courses, but for the population as a whole the outcomes are somewhat questionable. Like the lady in the beauty parlor, many feel incompetent to apply scientific method to everyday situations.

The outstanding characteristics of biology study are purposeful observation and intelligent reasoning, or reflective thinking. The student is constantly brought face to face with phenomena the interpretation of which requires the arranging of data, the drawing of inferences, and the formation of judgments. This method is by no means limited in its application to a broad range of natural sciences; on the contrary, modified to suit various requirements, it is characteristic, as well, of some work in such diverse fields as the social studies, mathematics, the study of

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[1]Harry C. Lassen, "The Scientific Method In Use," School Science and Mathematics L (1950), 529.

ancient peoples (anthropology, archaeology, ethnology), and of the structure of languages (grammar, etymology). Inasmuch, then, as it finds a place in investigations over such wide areas of human knowledge, a mastery of the techniques of scientific method is of extreme importance.

Our nation has three major needs for citizens adequately prepared in science. The most pressing need at the moment lies in the training of our future scientists. The second need lies in awakening and fostering interest in science careers early in the secondary school lives of our youth. The third need lies in training a general citizenry which can use the elements of scientific thinking in the solution of everyday problems of living, whether these problems be individual, community, or national in nature. It is hoped that by developing an appreciation of scientific method, the students will be better able to fulfill these needs.

Procedure

The material in this report has been gathered primarily for the writer's own edification.

Research on whether an appreciation of the scientific method can be taught satisfactorily will be cited and those techniques found to be successful by the author will be presented in the form of an outline giving procedures for making a course outline in biology.

Those techniques found useful by the author in teaching an appreciation of the scientific method are discussed under the headings:

A. The Independent Teacher
B. Use of Introductory Unit
C. Correlation With Other Subjects
D. Selection of a Teaching Philosophy
E. Use of Laboratory

Included at the end is a section containing a selected group of materials that might be used in teaching the scientific method and scientific attitudes.

Clarification of Terms

Actually, it is difficult to define "scientific method" except for purposes of gross identification and discourses. Bridgman's famous definition of the scientific method is as sound as any in its reflection of the myriad things that go on in the activities of the scientist at work. He stated, "The scientific method, as far as it is a method, is nothing more than doing one's damnedest with one's mind, no holds barred."[2]

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[2]Paul W. Bridgman, "Prospect for Intelligence." Yale Review XXXIV (1945), 450.

PART II

SOLVING THE PROBLEM

Review of Research

How students can best be trained in the habit of applying the scientific method as well as developing an appreciation of it will depend somewhat upon the way in which the course in science is organized. If the teacher is sufficiently independent in his own thinking and is unswayed by tradition of any sort and unhampered by limitations imposed by textbook, course syllabi, or pronunciamentos of the powers that be, he may, with his class, blaze a new trail so far as subject matter is concerned. He may do this even in spite of limitations, if he feels it important enough to take the risk that his pupils, though they may become trained in a superior way to use their reasoning powers, may fail at times to reach the standards of informational accomplishment represented by existing syllabi, examinations for promotion, and the like.

Our independent teacher may, for example, start out by bringing up some current incident or some demonstration performed with a minimum of explanation, in order that discussion may grow out of it. The purpose of the discussion is to get pupils to raise questions. He prefers that the question raising be done by the pupils, for several reasons: (1) he wishes them to get the problem-raising habit; (2) he wishes his class to be natural in their responses, investigating those problems which they

really want to know about rather than others imposed upon them; (3) he wishes to develop initiative, cooperation, and self-dependence on the part of his students. It may be that at times he will have to help along with problem questions of his own asking, but he will then encourage his pupils to adopt them as their own, and to formulate their own plans of attack in solving them.

All questions raised are carefully noted. Perhaps some are answered at once by other members of the group in a way that will fully satisfy the questioner; others may form the basis for investigation and report by an individual or small group; the remainder serves as a basis for further class planning and work.

It will be noted that in such a setting the usual steps in problem solving are present, once the problems are defined. In addition, as fast as the class is able to do so, it is given a part in determining procedures to be followed.

Use of Introductory Unit

Maurice Bleifeld states that one method used to accomplish these objectives is by using an introductory unit devoted to showing how many scientists have contributed to our present knowledge of biology.[1]

In this introductory unit, an attempt is made to give an understanding of the varied methods of science, as illustrated by the work of several scientists. Each scientist being selected because he exemplified a particular method of science. This unit would tend to point

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[1]Maurice Bleifeld, "Developing An Appreciation Of Scientific Method In Biology," Science Teaching Ideas II (1955), 6-8.

to the fact that there is no one scientific method; but that there are many scientific methods.

The scientists that could be selected, and the methods illustrated by their research, are as follows:[2]

Alexander Fleming--Insight shown in an accidental occurence.

Walter Reed--Importance of controlled experiments.

Frederick Banting--Reliance of scientists on the work of predecessors.

William Harvey--Direct observation and experimentation rather than reliance on ancient ideas.

Roy Chapman Andrews--Organization of extensive expeditions to gather evidence.

Charles Darwin--Patient observation over a long period of time.

Anton van Leeuvenhoek--Construction of one's own tools.

The pedagogical procedures used in this unit incorporates such activities as committee work, library lessons, and field trips. In addition, as each scientist is studied, suitable activities are taken up concurrently to exemplify a particular phase of work. Thus, laboratory lessons, demonstrations, field trips, and visual aids are used at appropriate times.

In order to synthesize the objectives of this introductory unit, the methods utilized by each scientists, and his contributions are summarized. This is followed by a trip to the school library in which each student is permitted to read about any scientist he chooses. Throughout the unit, students should realize that scientists of different nationalities made contributions of benefit to mankind as a whole.

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[2]Ibid., p. 7.

In later units dealing with disease, hormones, circulation, evolution, and cells, there can be or should be frequent reference to the topics covered in the introductory unit. By using a unit of this type, the students will have a chance to learn about the methods of scientists directly, as well as indirectly, by following in their footsteps.

Later lessons could be specifically planned to promote the use of the elements of the scientific method. Such a lesson would provide:[3]

1. A review of previous learnings and their application in a situation which requires analytical and creative thinking.

2. An appropriate opportunity to "do science" and to experience an enriching, motivating activity.

3. An opportunity to use the following elements of scientific method and scientific attitude, although not labeled as such, as the tenth year level of ability and understanding:

   A. Verifying one's own work by considering the trials of others who are doing the same thing.

   B. Suspending judgment.

   C. Accepting the results of the exercise of one's own powers, instead of those of authority alone.

   D. Proposing hypotheses.

   E. Gathering data for the testing of hypotheses.

   F. Summarizing the data.

   G. Selecting the best conclusion when the safeguards are understood.

This type of lesson is motivating and allows the pupil to use what he has learned and understood earlier to reach new levels of accomplishment.

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[3]Milton Lesser, "Providing For The Teaching Of Some Of The Elements Of Scientific Method," Science Teaching Ideas II (1955), 11-12.

Correlation With Other Subjects

Warren J. Anna believes that biology in itself is interesting to the majority of students, but when a little garnish is added, what can be done defies the imagination.[4] It is taken for granted that the biology room should have many displays of the "flora and fauna," but there are many different ways in which biology may be correlated with the other subjects in a school curriculum. Let's take several cases:

The school library--try running a general-interest display in the library for students who do not come in contact with biology in their courses. Set up a skeleton with proper labeling, as an interest catcher, zoological specimens and charts, botanical specimens and charts, and several other displays. Find in the school library books and magazines whose subject matter is biological in nature and display them in an interesting fashion in your classroom. Then illustrate each of these books and magazine articles with a specimen to signify the title of the book or to show an important detail of the story.

Your bulletin board--it is easy to find enough material in newspapers, magazines, and pamphlets on biological subjects and interest to keep a lively bulletin board display before your students. Use the plan whereby every other week students in a particular class be responsible for the bulletin board. Have a class committee that is responsible for the board.

A display can be found to show correlation between almost any subject and biology, if the teacher is willing to work it out. By working a bit extra, one can dig out the materials that are needed and their applications.

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[4]Warren J. Anna, "Garnish Well, and Serve," Clearing House XXIV (January, 1950), 305-6.

Selection of A Teaching Philosophy

The good teacher constantly selects from the vast experiences of mankind those which may produce desirable changes in the young people he leads. The kinds of experiences he will select should depend on the students he teaches, and a knowledge of their gifts and opportunities. Unfortunately, in many instances, the kinds of experiences he selects are often circumscribed by inadequate training, by poor facilities, by unsympathetic administration, by rigid adherence to courses of study. All too often, a syllabus or textbook is taught--not the student.

The acceptance of a teaching philosophy based on the needs and interests of students precludes rigid courses of study, inflexible teaching procedures, and unsympathetic administration. But it does not mean that the experiences around which the course is organized are derived entirely from the students' interests. A need is defined as an interaction between the student and his community.

The student's personal problems are important, but their solutions, be they personal, social, or economic, depends on the community, its needs and its interests. The student's interests serve as motivations, not as an end.

To be specific, Mr. Syllabus, our teacher who depends on a more or less rigid course of study knows what he's to teach before he meets his students. When he meets them, he may ask for a definition of biology, or ask for a definition of life, or parade the animal kingdom before them, or tell them just what he expects, how he wants notebooks or homework done. This is not to say that a syllabus cannot be based on the needs and interests of students. But most syllabi are based on what the teacher thinks his students' interests are (on the past, so to speak)

and not on the interests of the class he will meet.

Mr. Needs, our teacher who will plan his work around needs and interests, knows several things before he meets his students. He has made a study of the community in which his students live. He knows the diseases which kill and maim, the needs and interests of the majority of people in the community and the opportunities available for biological experiences. When he meets his students, he meets them as a guide and as an experienced friend. He will ask--"What do you want to know?" What will they need to know to be fitted for life in their community in this world?

His class, of which he is an important but not the whole part, will take a week or so to plan the course of study for the term. This friendly cooperative planning enables Mr. Needs to gauge the interests and needs of his students. He establishes a rapport which Mr. Syllabus usually never attains. And in so doing the students will participate in a characteristic activity of the scientist--careful planning to solve problems. Mr. Needs recognizes that there is all the difference in the world between teaching subject matter as an end itself and teaching subject matter to solve problems of living in a specific community.

Use of Laboratory

Perhaps one of the best ways to develop an appreciation for scientific method is by correct use of the laboratory. According to Edward W. Stefanials, the work in the laboratory should precede classroom recitation.[5] The laboratory is of little value if it degenerates to the point where

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[5]Edward W. Stefanials, "Functional Scientific Method," School Science and Mathematics XXV (June, 1950), 206-8.

students perform experiments to find out what they already know. This is the case when classroom recitation precedes the laboratory. The laboratory should be a research center, a place where students discover principles and learn the laws of science. The student needs to have the type of directions which will lead him to experiment, observe, record, discover, and draw conclusions. The nature of the laboratory makes it imperative that he make several trials and arrive at conclusions. There should be enough trials to make it possible for the student to generalize, and he should be encouraged to make application of the principle learned. This application may be a statement of the practical use of the principle learned or it might be the analysis of a problem in the laboratory involving the same principle.

Wherever students get the opportunity to meet scientists or to work for them, the experience is of value. Students may be sent to visit science laboratories, or attend national or state conventions. These students can then report on the activities of the scientists to their classmates, the school paper, and the school magazine.

One of the most fruitful ways for students to get direct information about the activities of scientists is to ask a former student who is majoring in biology or some other science at a university to return from time to time and report on the activities there. Former students in science training returning to their previous haunts have a healthy and stimulating effect on the student in school, since developing strong motivation is still a function of the school.

Analysis and Synthesis

Different lists of elements of scientific method have been presented by many writers, any one of which would not be accepted by all. Furthermore,

the methods, techniques, and materials used by scientists as they work are so interrelated that it is difficult to compose in general terms a conclusive list of elements of scientific method.

To attain the objective of developing the elements of scientific method, instructional procedures must provide direct experience in problem solving. Indirect teaching will not produce the outcomes desired. Teachers recognize that providing such direct experience involves a way of living in the classroom. Only in a permissive atmosphere which encourages students to express feelings and stimulates curiosity which leads to questions of "why," "how," and "what," can students develop the ability to do causal thinking and to manipulate situations necessary for problem solving.

Many opportunities which stimulate scientific thinking occur each day in classrooms. Carefully planned field trips, bulletin board arrangements, displays, movies, and careful observation of natural scientific phenomena in everyday life encourage students to identify problems. Teachers lead pupils to identify, clarify, and state problems by posing stimulating questions for which there are no ready answers; by performing demonstrations which cause pupils to ask questions and by encouraging free discussions rather than by nicely "handing out" problems to be solved.

The student who can acquire the ability to apply the scientific method toward the solution of problems he faces is at a decided advantage. The specific value obtainable from its use will be in direct proportion to the ability of the student to master its practical applications in many types of difficulties he encounters in everyday life. Obviously, his appreciation of the scientific method as a usable technique cannot

come about from the mere ingestion of a few lectures or a few articles on the subject. Meaningful use and practice of the method by each student is essential. For the teacher who recognizes each student as an unique personality, and who tries to teach his students as individuals, the problem of adapting the method to best meet the individual's needs becomes great and the obstacles to be overcome difficult. The teacher can, in a very general way, make at least a beginning by utilizing one or more of the following techniques:

1. Provide students with a simple explanation of the scientific approach and its uses, and provide an opportunity for each student to practice the techniques in simple ways.

2. Try to help students to make accurate observations, and group these observations into logical conclusions in a variety of situations and under a variety of conditions.

3. Try to develop in students the ability to see things in true perspective, and how to relate things to reality and practical living, that they may more effectively utilize their newly-gained knowledge of scientific procedures more advantageously.

4. Encourage use of the scientific method in solving problems encountered outside the classroom and in other classes.

Before a teacher can lead students to develop appropriate attitudes and habits of thinking, he must know not only what these attitudes and habits are and how to use them but, most important of all, he must have them himself. Scientific habits of thinking are not acquired by reading books, listening to lectures, observing demonstration lessons, memorizing lists of scientific attitudes or watching other people solve problems. They can be developed mainly by frequent practice of the scientific method in the solution of specific problems.

PART III

A PROCEDURE FOR ORGANIZING A BIOLOGY COURSE OUTLINE

This particular outline was established after much time and effort was spend in reviewing the research that had been completed on the scientific method, and the ways of teaching an appreciation of this method.

After using this outline in the classroom, the author feels that it can be recommended as a good procedure to follow in organizing a course outline for teaching an appreciation of the scientific method.

"A child learns what he experiences and becomes what he learns." If this is true, the learning experiences of a child should be taken from the environment in which he lives. Information intangible to the child's own way of life does not fit into his personality and may lead to confusion. Such a confusion brings on mechanical interpretations and make-believe situations which are from his environment, it appears that he may act more intelligently when demands are made of him now and in the future. Students who are given a chance to help in the interpretation and attempted solution of their own problems are led, in some degree, to change their opinions to coincide with those ideals leading toward unity, co-operation and fair play in a community. The community must have the co-operation of all of its members in answering the demand of our great society.

Since the school is one of the agents that aids in the development of youth, schools like other agencies in the community, must turn their

attention to some of the problems youth encounters, and some of the needs peculiar to individuals. So in order that our goals in science might be stated in terms of life situations and needs, various techniques are used to determine the needs of the group. General information sheets are filled out to get a clearer picture of the student's home life, health conditions, desires and problems.

We attempt to have our science courses consist of a series of units which have been selected and organized from subject matter collected by students, the teacher, and from other available sources. Efforts are made to center these units around the major objectives in the light of the pupil's needs. Therefore our general objective in the Biology classes is, "Science for Better Living."

Our general way of working has not changed but the instructor has found it necessary to make changes along the following lines:

1. Give more detailed explanations of topics.
2. Change requirements and procedures of certain units of study.
3. Give more detailed information about how to gather material for reports.

Our Way Of Working

The units in our biology classes are developed around the things the group wants to understand and know about. The units are arranged in order of greatest importance to the students in that class. Students and teacher plan the way of working, the materials to be used, group obligations, and due dates. The way of working may look something like this:

I. Planning Period

   A. Pre-planning period
   B. Motivation period

1. Listing immediate objectives for each unit
2. Listing activities to be engaged in during the study
3. Organizing the class for work

    a. Group organization
    b. Individual workers
    c. Explanation of duties of groups and individuals
    d. Preparing written report on organization of group or individual work to be accomplished

C. Pupil-teacher planning

1. Discussion of problems
2. Working out temporary objectives
3. Suggesting topics for study
4. Selecting a unit or units

II. Work Period

A. Students divide into groups
B. Groups plan the work to be presented to the class

1. Groups plan how material will be presented
2. Securing advice from instructors, the librarian and other sources
3. Working through
   (During this period the instructor offers help to individual students and groups in working with the material at hand.)

C. Presentation by groups and individuals to the class

1. Questions
2. Discussions
3. Criticisms

III. Period of Evaluation

A. Some form of testing
B. Results of observations
C. A discussion period
D. Summary of work covered

Topics Listed For Study

The Function of the Human Body
Sex
The Blood
Reptiles
Reproduction
Community Remedies
First Aid
Harmful Insects
Cosmetics
Botany
Diseases
The Brain
Mammals
The Frog

Heredity
Mental Illnesses

Superstitions
The Spaceman

Preparing For Study

With the preceding information in mind the teacher plans some goals to be reached and important subject matter to be studied. This information is used to plan with the students the work for the year. Plans are flexible and may be changed to meet an urgent need either in the environment or classroom.

The units of study may look something like this:

THE COVERING OF THE HUMAN BODY

The subject was introduced by the instructor. Students were motivated to ask questions. After the questions were listed on the board the instructor saw the need for a more detailed study on some questions than on others. Study was carried out in this manner:

I. Introductory period by instructor (Table I)

- A. Review of goals
- B. Connect goals to present subject matter
- C. Introducing present subject matter
- D. Listing of questions asked by students and teacher

II. Group work on questions by students

- A. Assigning of work decided by students
- B. Groups to be organized by students with the help of instructor
- C. Dividing into groups
- D. Preparing for presentation

    1. Research
    2. Drawing
    3. Preparing panel discussions
    4. Other activities

III. Reporting to the class

- A. Question and answer period

B. Explanations by instructor

IV. Review
(Stressing important points to be remembered.)

V. Period of Experimentation

A. Students may choose experiments selected by the instructor or they may select experiments of their own interest. (Table II)
B. After experiments have been performed in the laboratory results are reported to the class.

VI. Review

A. Paper and pencil test
B. Summary of work covered including points to remember
C. Evaluation of group work

Our Objectives in Science Teaching

The immediate objectives in the units would depend upon the unit to be taught at a particular time. Objectives such as:

1. Helping students to acquire knowledge about the earth's resources and the need for conservation.
2. Helping students to learn and apply the principles of the scientific way of thinking and solving problems.
3. Acquiring knowledge and skills in experimentation both in the classroom and outside of the classroom.
4. A knowledge of diseases, including symptoms, possible treatment and cures.
5. Helping students to learn about the anatomy and functions of the human body.
6. The relationship between man and his environment, including how each one depends upon the other, helpful and harmful living things.

And so the objectives may be grouped into four catagories:

1. The acquisition of information
2. The development of methods of thinking
3. The induction and application of principles
4. The formation of attitudes

If there is any one thing that the study of science should do for the student, it is to produce a scientific attitude toward all problems that arise in a changing society.

TABLE I

QUESTIONS LISTED BY STUDENTS AND TEACHER

FOR A UNIT ON THE SKIN

1. What causes a person to become bald headed?
2. What causes skin color? Give historical background.
3. What do dyes and bleaches do to your hair?
4. Is it better to use soap on the skin or cream?
5. What factors determine the color and length of the hair?
6. What are some of the factors that cause face powder to be desirable?
7. What is acne?
8. Where do hair and fingernails come from?
9. What is dandruff?
10. Name the layers of the skin.
11. What is a mud pack?
12. What causes black heads?
13. What causes hair to turn gray?
14. Why do we perspire?
15. What are some danger signals of skin cancer?
16. Does shaving make the hair more like bristles?
17. What does food have to do with skin?
18. Why do some people sunburn and others don't?
19. Discuss the care of the skin.
20. Draw a section of the skin.
21. Name 5 diseases of the skin, cause, treatment or cure.
22. What is the function of the skin?
23. Do your hair and nails continue to grow after death?

TABLE II

TESTING COSMETICS

I. Testing face powders

A. Materials

1. Four commercial brands of face powders
2. Iodine
3. Test tube
4. Miscroscope
5. Slides and cover glasses
6. Test tube holder

B. Procedure. Testing for starch in face powder

1. Place a small amount of face powder in a test tube containing 5cc of water
2. Bring the mixture to a boil
3. Add a few drops of iodine
4. Record your results
5. Repeat procedure for each brand

C. Procedure Number Two. Testing for fineness of texture

1. Put a very thin coat of each powder to be tested on glass slides and place a cover glass over each
2. Place the slides under the microscope and observe the size of the particles of the powder
3. Record results
4. Draw conclusions

II. Answer these questions about face powder:

1. Is starch present in the face powder that you tested?
2. Is starch desirable or undesirable in face powder? Why?
3. How is powder manufactured?
4. Are large or small particles desirable in face powder? Why?
5. What simple hand test can be made to determine the fineness of face powder?
6. How is the price of a face powder determined?

PART IV

SUMMARY AND CONCLUSIONS

Summary

Scientific thinking is stimulated and methods of work are developed when teachers guide students into the solution of problems they have raised, rather than relying upon "ready-made answers."

Students may be stimulated to use and appreciate scientific method only to the extent that teachers provide for such experiences by "doing science" rather than by just reading about science or by giving direct answers to questions asked by the students. To provide this type of experience, the classroom becomes a laboratory for solving problems. Laboratory group experiences cause pupils to examine causes and conditions, to share ideas, and to evaluate differences of opinion, to look for facts and evidences, to look for strengths and weaknesses in their own ideas as well as in those of others. As solutions for stated problems are undertaken by individuals or small groups of students, skill in the collection, analysis, interpretation, and evaluation of data is developed.

Through this type of experience, students gain an understanding of scientific method, and they gain a keener appreciation of the lives and works of scientists of the past and present. Just reading and talking about science will not effectively stimulate the use of the scientific method. Instead, students must be provided opportunities for recognizing

problems and ways of solving them. The teacher must provide the motivation and guide the learning process in order to stimulate scientific thinking and to emphasize problem solving.

The wise teacher not only utilizes the possibilities of a natural problem and the immediate interest of the pupils, but also recognizes and stimulates the natural desire of students to explore, to question, to try out or to experiment, and channels eager curiosity into worth-while learning activities and organizes the course about these ideas. As a result of this, the student will develop an appreciation of scientific method.

Conclusion

To help high school biology students develop an appreciation of the scientific method and its importance in our lives today we should make use of a variety of activities. We need to develop the idea that the scientific method is not a rigid step-by-step procedure but a pattern of behavior that develops when individuals seek the solution to a problem in a systematic way, and that, like all patterns, it may be altered to fit any situation. We also need to see that every student takes an active part in the use of these methods; it is not enough to study about them.

No matter what pattern or the kind of course adopted, the course in biology has its special flavor, and its special problems.

Biology is essentially a study of living things and things that have been alive in the past. It is "living things" which give biology its special flavor and interest. It is "living things" which also present the biology teacher with his problems, for the maintenance of living things requires time and care. If the course encourages the young people

in his class to take part in studying their own biology, the course not only concerns itself with a study of living things, but is alive as well--alive with the interests of young people in life and living.

SELECTED RESOURCES

This section contains a selected group of materials that might be used in teaching the scientific method and scientific attitudes. In many issues of the following publications, information on this subject may be found: The Science Teacher, The American Biology Teacher, School Science and Mathematics and Science Education. There is no attempt here to single out articles in these magazines. An interested reader would do well to consult the index issues for recent years.

MOTION PICTURES

1. Louis Pasteur--Man of Science, Sterling Films, 1951, 30 minutes, sound. The scientific activities and discoveries of Pasteur from 1856 to 1895.

2. Madame Curie, Teaching Film Custodians, 1943, 24 minutes, sound. Traces the long work of the Curies in separating radium from pitchblende.

3. Man Against Microbe, Metropolitan Life Insurance Co., 1932, 10 minutes, sound. The life of scientists engaged in work on disease.

4. Science and Superstition, Coronet, 1947, 10 minutes, sound. Illustrates the use of the scientific method in everyday problems. Shows how science disproves superstitions.

5. Scientific Methods, Encyclopedia Brittanica Films, 1954, 12 minutes, sound. The steps of the scientific method and applications to real life. Traces the method in the thinking of Fleming's discovery of penicillin.

6. Using the Scientific Method, Coronet, 1952, 11 minutes, sound. Stresses the attitudes so necessary for successful use of the scientific method.

7. What is Science?, Coronet, 1947, 10 minutes, sound. Exposition of the meaning of the word through the steps in the scientific method.

HISTORICAL MATERIALS

Encyclopedias, Biographies and many publications like Scientific American, Science Digest are good sources of historical material.

1. Great Experiments in Biology, Edited by M. L. Gabriel and S. Fogel, 1955, Prentice-Hall Inc., Englewood Cliffs, N. J. $3.75.

2. Health Heroes, School Health Bureau, Metropolitan Life Insurance Company, New York, N. Y. A series of booklets on such men as Pasteur, Koch, Jenner and others. A series of filmstrips is also available but it must be specifically asked for. Free.

3. History of Science Cases for High Schools, Graduate School of Education, Harvard University, Cambridge 38, Mass. The Harvard Case Studies on a high school level. Sample copy is free.

DEMONSTRATIONS AND LABORATORY EXERCISES

1. Demonstrations in Science, 1958, Texaco Research Center, The Texas Company, Beacon, N. Y. Free.

2. Demonstration Abstracts, Journal of Chemical Education, All of the 1957 and 1958 issues to date contain these abstracts of demonstrations that have appeared in the magazine in the past.

3. "Open-Ended" Experiments, Manufacturing Chemists Association, Inc., 1625 Eye St. N. W., Washington 6, D. C. Thirty student guides and one teacher information sheet are available free to each school.

4. Superstition to Supersonics, Manufacturing Chemists Association. Teachers book is 17¢ per copy and consists of demonstrations. The student book is 7¢ per copy and consists of exercises on the level of general science.

PROJECTS

1. Encouraging Future Scientists: Student Projects, National Science Teachers Association, 1201 16th Street, N.W., Washington 6, D. C. 1954, 50¢ for one copy, 25¢ for two or more.

2. If You Want to do a Science Project, National Science Teachers Association, 1955. same address as in 1. 50¢ for one copy, 25¢ for two or more.

3. Science Projects as Stepping Stones to Careers in Science, National Science Teachers Association, 1956, same address as in 1. Free.

4. Science Clubs of America: Sponsor Handbook, Science Service 1719 N. Street N. W., Washington 6, D. C. $1.00 each.

5. Thousands of Science Projects, Science Service, same address as in 4. 25¢ each, 10 copies for $1.00.

TESTS

1. Ability to Interpret Reading Materials in the Natural Sciences, Iowa Test of Educational Development; Test 6. Science Research Associates, Inc. 57 W. Grand Avenue, Chicago 10, Ill.

2. Logical Reasoning Test, Cooperative Test Division, Educational Testing Service, Princeton, N. J.

3. Test of Critical Thinking, For grades 7-9. University of Oregon Press, Eugene, Oregon.

4. Test of Application of Principles in Physical Science: General Education Series, Cooperative Test Division, Educational Testing Service, Princeton, N. J.

5. Test of Application of Principles in Biology: General Education Series, Cooperative Test Division, Educational Testing Service, Princeton, N. J.

6. Test of Application of Principles in General Science: General Education Series, Cooperative Test Division, Educational Testing Service, Princeton, N. J.

GENERAL TEACHING METHODS

1. Selected Science Teaching Ideas of 1952, National Science Teachers Association, 1953, 1201 16th Street N.W., Washington 6, D. C. $1.00 to members, $1.50 to all others.

2. Science Teaching Ideas II, National Science Teachers Association, same address as in 1. 1955, $1.00.

3. Science Teaching Through Problem Solving, National Science Teachers Association, 1956, same address as in 1. $2.00.

4. Star Ideas in Science Teaching, National Science Teachers Association, 1957, same address as in 1. Free.

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