THE DEVELOPMENT AND EVALUATION OF SOME BEHAVIORAL OBJECTIVES FOR THE LABORATORY OF A NON-MAJOR COLLEGE LEVEL COURSE IN GENERAL BIOLOGY

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CHAPTER I

INTRODUCTION

Laboratory methods in general have been developed by teachers who were specialists in their field, who looked upon the courses they taught with the particular vision of the specialist, and who saw in such courses preparation for academic specialization or for vocational specialization. On the other hand, it is well known that only a small percentage of the students who undertake general biology courses involving laboratory ever pursue them further than the elementary course. Consequently, the question as to the value of such courses to students who do not become specialists in the science fields becomes an important one.

Another question is equally important. Can the desirable outcomes of laboratory methods of teaching be attained efficiently with less expenditure of student and instructor time than they are at present? Furthermore, there is considerable evidence that in the organization of laboratory courses so much attention has been given to detail and organization that the values of application have been, to a considerable extent, overlooked.

In undertaking an analysis or evaluation of the laboratory teaching methods for the non-major, it has been a somewhat common practice to set up experimental control classes as a situation in which evaluations and comparisons can be made. Usually the comparison is then made on the basis of a test or examination which measures the mastery of the subject matter. When the results seem unfavorable to laboratory procedure, the objection is raised that such evaluations are inadequate since they are not based upon the objectives of laboratory methods of teaching. This objection is entirely valid and has been recognized by experimenters in their reports of experiments. Always standing in the way of studies of this type is the difficulty of stating and measuring these desirable outcomes of laboratory methods of teaching.

Rasmussen (1970) states:

> Laboratory work is widely recognized as an integral and essential component of biology courses at all levels. The reasons for performing a particular laboratory activity or the rationale for a total laboratory program are, unfortunately, not always understood by either the students or the faculty.
>
> Why do most biology courses include specific amounts of time assigned to laboratory experiences? (as a matter of prestige, generally the more lab time, the better). What are these long periods in the laboratory supposed to accomplish? What are the determinants of the nature of the objectives and the activities in the secondary (and usually the collegiate) biology laboratory?

Purpose of the Study

There has not been been, with few exceptions, any concerted attempt made either to state the goals of the laboratory of a college level non-major introductory biology course in behavioral terms or to determine those behavioral objectives which are acceptable to the majority of the instructors who teach that particular course. In addition, there have been few attempts to determine whether particular characteristics of the instructor, his education, or his institution might have some effect on the choice of specific behavioral objectives.

The purpose of this study is to establish a list of behavioral objectives acceptable as learning outcomes of the laboratory of a college level general biology course. It is further the purpose of this work to determine whether particular characteristics of the instructors, their education, or their institutions, have any effect on their choice of those behavioral objectives.

The new curriculum developments, especially in the fields of elementary science as exemplified by AAAS, SCIS, ESIS, and in the fields of secondary science as exemplified by BSCS, CBA, CHEM, and PSSC, have given the laboratory a much more significant place in the teaching of science than it had formerly been given.

The same increased emphasis, however, has not been given to the teaching of the non-major general biology courses at the collegiate level. The only significant organized effort to consider the undergraduate biology curriculum have been those efforts of the Commission on Undergraduate Education in the Biological Sciences (CUEBS). Even then just a small part of the effort has been devoted to the role of biology in the liberal education of the non-major. The role of the laboratory has come in for an even less significant proportion of the scrutiny when one realizes that a total of four pages was given to the role of the laboratory in the summary report entitled Biology in a Liberal Education (1967) which was a colloquim attended by thirty-six of the most prominent figures in biology education today. In the summary report entitled Biology for the Non Major (1967) there were six pages devoted to the laboratory. This latter report was a compilation of responses to a questionnaire sent to sixty-seven members of CUEBS. The consensus statements from both groups can be summarized as:

1) The laboratory is not a primary necessity for a non-major biology course as reported by the latter group;
2) The laboratory is the most important part of any introductory biology course as reported by the former group;
3) In neither case were the criteria for the planning of laboratory work based on the development and growth of the student, but rather on the characteristics and peculiarities of the discipline, i.e.,
   - A. Familiarity with many of the tools of biology,
   - B. Maximum use of live materials,
   - C. Experiments capable of being completed,
   - D. Prompt presentation to students of an exciting open ended situation during the first or second meeting,
   - E. Inclusion of certain concepts of measurement using biological materials
   - F. Coordination of laboratory sessions with lectures,
   - G. Use of small reading rooms with books and reprints,
   - H. Avoidance of over emphasis on lab reports and drawings.

When one realizes that these people through their departmental, institutional, and national positions of influence literally dictate the curriculum practices, funding practices, teaching practices, preservice teacher training practices not only of elementary and secondary candidates but also of those students who will ultimately occupy the office of the undergraduate and graduate faculty, it becomes imperative that criteria be established by which the merits of teachers, of practices, and of programs can be evaluated. This has not been done for the non-major biology laboratory.

Dean (1970) states:

> The university has two major functions: the discovery of knowledge and the dissemination of knowledge. It is generally agreed that the research performance of American universities is discharged with distinction, but it would be hard to find someone who would claim that the teaching function is characterized by equal quality.
>
> One consideration makes any neglect of teaching particularly serious: the university is almost the only place where one can earn the credentials to become a college teacher.
>
> Recently, the public has been made acutely conscious of the inadequacies of undergraduate education. It is time to attack the problem at its roots--the preparation of the college teacher.

Humphrey and Wise (1968) report on an unpublished study:

> Of 1843 people granted Ph.D.'s in biological fields by 94 leading universities in the period 1963-1967: 69% became college teachers of biology and of these 73% taught a beginning course. Of these 94 universities: 66% provided no special training to teaching assistants before they taught, and 80% offered no special course or seminar in any aspect of college teaching.

Dean (1970) comments on a conference attended by 14 recent graduates with brand new Ph.D. degrees who had taught for one year and by 9 graduate students:

> Recent graduates and graduate students felt a great need to experience a broad spectrum of the activities to be expected of them as teachers. Almost none had had experience in lecturing, educational planning, development of new laboratory experience, or even in preparation and ordering of materials.

Koen (1970) categorizes the activities and competencies of college teachers under six headings as:

1. content mastery,
2. the ability to organize a domain of knowledge, to design and plan a course, to establish instructional objectives,
3. effective presentation skills--the "management of learning",
4. personal interaction with students both inside and outside the classroom,
5. ability to rigorously evaluate one's own teaching effectiveness, and

6. professionalism.

and further identifies a set of tasks in which college teachers are expected to exhibit some competence:

> . . . those related to the organization of a domain of knowledge--choosing topics and sequencing them to make a coherent whole, choosing reading lists, deciding on appropriate ways to evaluate the academic performance of students, and establishing instructional objectives. I would agree that the last-named component is really the most important, because if the teacher can clarify for himself what he expects the student to accomplish, he will have provided himself--and his students--with a conceptual basis for making all the other decisions. This is a step that is too often overlooked, mostly because college teachers usually lack a systematic framework for thinking about the problem, central though it is.

Koen continues:

> . . . it is necessary for the individual teacher to have clearly fixed in his mind what he is trying to accomplish when he undertakes to teach a course . . . instructional objectives can be reviewed for their appropriateness to the discipline, the character of the institution and the department, and the level of the student. The best, indeed, the only, criterion for these decisions is the considered judgment of scholars in the discpline. The effective teacher can then be defined as one who sets up objectives and attains them. The good teacher is the effective teacher who attains the "right" objectives, i.e., those that are congruent with the highest scholarly judgments of desirability and appropriateness. . . . The individual's increasing effectiveness as a teacher can be defined in terms of the degree to which his students' achievement approaches his present goals and/or the degree to which his goals increase in sophistication.

Hurd (1961) summarized the results of studies on laboratory work as follows.

> The interpretation of the studies on individual laboratory work versus laboratory demonstrations is dependent upon the assumptions one makes about the purposes of laboratory instruction. If an exercise is simply to acquire a knowledge of facts or to reinforce their retention one procedure is as good as the other. The choice of a particular method, an individual experiment or a demonstration, is a question of economy either in time or cost. Economy favors the use of laboratory demonstrations more than individual work.

On the other hand, if it is assumed that a student learns to understand the nature of science through "sciencing," then intuitively it seems necessary that the student be involved in an investigative or research activity. Under those conditions he is engaged in planning experiments, collecting and managing data, formulating results, interpreting his "conclusions" and subjecting these to further verification or criticism. The success of the student and the effectiveness of the experiment are judged in terms of how effective was the exercise in developing critical thinking and providing experience in the 'ways' of science. Measures of this sort were not generally used in comparing individual laboratory work with teacher demonstrations, although some researchers were cognizant of them. One is forced to conclude from the research on laboratory work in biology courses that if the objectives are to understand science, or to acquire knowledge, the usual observational exercises, drawings, and 'cookbook-type experiments' have produced disappointing results.

The Scope of the Study

There are in existence today many different kinds of general biology courses and many different kinds of laboratories. Each course offered is the ultimate product of several major factors. Some of these factors are: the function of the institution, i.e., university, state college, private liberal arts college, junior college; the tradition of the department in which the course is offered; the goals of the society and the times in which the course is offered; and the content and structure of the discipline in which the course is offered. But the primary factor involved in the actual planning, organizing, operating, and evaluating of a course is that instructor responsible for the course.

Just as a course is the resultant product of many variables, the instructor himself is the resultant product of many other variables. There is available a great deal of research relating to the character and personality of teachers as they influence the day to day activities of the classroom. There is not, however, a similar abundance of research pertaining to the characteristics of an instructor as they relate to the planning, organizing, operating, and evaluating of a course. Some of the characteristics serving as possible contributors to the instructors' perception of the functions and organization of the laboratory are: his concept of general education, his aspirations relative to research and teaching, the character of the instructor's undergraduate degree institution, the instructor's highest academic degree, the number of credit hours of education courses earned by the instructor, the number of years of secondary school teaching experience served by the instructor, the character of the institution at which the instructor is presently teaching, the instructor's involvement in graduate level instruction, the presence of a graduate program at the instructor's present institution, the number of years of college level teaching, the number of years of experience of teaching the particular course under consideration, whether or not the instructor chose to or was assigned to teach the general biology course, whether the instructor is male or female, and the number of semesters the instructor spent as a teaching assistant in that particular course.

In order to compare the various characteristics of the instructors, it was first necessary to develop an instrument. This instrument was developed by identifying the goals of general education, subdividing these into goals compatible with science education, and further subcategorizing these into the goals of the laboratory.

Gideonse (1969) states:

> What criteria (or whose) should we employ in our attempt to better the practices, processes, materials, and organizational forms by which we carry out instruction and education?

> . . . there is another aspect of criterion measures dealing with the idea of who is choosing what kinds of objectives. . . . On what grounds should the nation accept the academic disciplines as the most suitable structures within which curricular objectives should be chosen. . . . These challenges boil down to one essential question: who should set the objectives for curriculum development anyway? Should it be the academicians alone, or in concert with educators, or in concert with the lay public, or in concert with the young, who after all will live in and with the future we have invented for them?

It is the position of this present study that the objectives for any course must be chosen from and be compatible with the goals of society, the goals of the institution, the goals of general education, the goals of the discipline, and the goals of the student. But ultimately it is the instructor of a specific course who makes the decision as to what will be taught and the manner in which it will be taught.

It is not the purpose of this paper to attempt to judge good or bad teaching or planning. It is the purpose, however, to attempt to establish a list of historically valid objectives from as many reputable sources as practicable and to submit this list for evaluation to teachers responsible for the non-major general biology laboratory. Through this method, it is hoped that it will be possible to establish a rather specific list of behavioral objectives which are acceptable to a majority of the instructors responsible for that course or for one very similar to it.

Montague and Butts (1968) define a behavioral objective as: ". . . a goal for, or a desired outcome of, learning which is expressed in terms of observable behavior (or performance, if you prefer) of the learner."

Kurtz (1965) states it a little differently when he asks:

> What do I want my students to be able to do after taking my course that they couldn't do before enrolling in it? In other words, don't ask yourself, 'What will they know?' but do ask 'What will they be able to do?'

Mager (1962) lists several action verbs that can be used in the writing of behavioral objectives. He identifies the following:

Classify	Describe
Distinguish	Construct
Design	Apply
Calculate	Order
Select	Demonstrate
Formulate	State
Write	

Eiss (1968) in reporting on a Conference on Scientific Literacy states:

> One discovery was that many of the statements of scientific literacy when catalogued in Bloom's categories for the affective domain were primarily cognitive in nature, although perhaps at a higher level of cognition than the ones Bloom identifies as such. Also, all of the goals in the affective domain are based upon and probably inseparable from, cognitive knowledge. . . . This would indicate that we need a much larger list of behaviors for the affective domain than those suggested for the cognitive. Also, these behaviors will not be described in as precise terms, nor measured with the same type of instruments as are the behaviors in the cognitive domain.

A partial list of action verbs useful in writing objectives in the affective domain is:

selects	inquires	participates	consults
challenges	criticizes	joins (groups)	refrains
reads	chooses	specifies	listens
reports	persists	compares	discriminates
predicts	organizes	hesitates	undertakes
recognizes	accepts	supports	adapts
asks	synthesizes	comments	insists

Mager further states:

> An objective is meaningful to the extent it communicates an instructional intent to its readers, and does so to the degree that it describes or defines the terminal behavior expected of the learner.

> A terminal behavior is defined by identifying and naming the observable act that will be accepted as evidence that the learner has achieved the objective and describing the conditions (givens, restrictions) necessary to exclude acts that will not be accepted as evidence that the learner has achieved the objective.

It is the scope and purpose of this study to establish a comprehensive taxonomy of terminal behavioral objectives for the non-major general biology laboratory as perceived by those instructors in every institution of higher education in the state of Missouri who are responsible for planning, organizing, operating, and evaluating that course. It is further the purpose of this study to determine whether or not any relationship exists between each of several characteristics of the instructor and his institution and his perception of the function of the laboratory.

This study will form the basis for a much larger study in the area of learning outcome specification for general biology laboratories at the collegiate level. It also will form the basis for a much larger study in the area of preservice preparation for college biology teachers.

The procedures involved in an attempt to determine these relationships will be (1) the selection of the instructor group to be studied, (2) the selection of the goals and behavioral objectives to be used in the study, and (3) the analysis of the data collected from the questionnaire. Details concerning the questionnaire and statistical treatment will be found in Chapters III and IV and the Appendices.

Hypotheses

The following hypotheses stated in the null form will be tested:

1. There will be no difference in the choice of behavioral objectives by instructors in universities, private liberal arts colleges, state colleges, and junior colleges.

2. There will be no difference in the choice of behavioral objectives by instructors who are female and those who are male.

3. There will be no difference in the choice of behavioral objectives by instructors who are in the age brackets 25-30, 31-36, 37-42, 43-48, 49-54, 55-65.

4. There will be no difference in the choice of behavioral objectives by instructors who have had 0 years, 1-3 years, or four or more years of high school teaching experience.

5. There will be no difference in the choice of behavioral objectives by instructors who view their major professional function as teaching and those who view their major professional function as research.

6. There will be no difference in the choice of behavioral objectives of instructors whose highest earned degree is the doctorate and those whose highest degree is the Master's.

7. There will be no difference in the choice of behavioral objectives of instructors who earned their undergraduate degree in a university, private liberal arts college, or a state college.

8. There will be no difference in the choice of behavioral objectives by instructors who have taught the non-major biology course 1-3 years and those who have taught it four or more years.

9. There will be no difference in the choice of behavioral objectives by those instructors who chose to teach the course and those who were assigned to teach it.

10. There will be no difference in the choice of behavioral objectives by instructors who have majors enrolled in the course and those who do not have majors enrolled.

11. There will be no difference in the choice of behavioral objectives of instructors who hope to recruit new majors from the students enrolled and those who do not hope to recruit new majors.

12. There will be no difference in the choice of behavioral objectives by instructors whose general biology course enrolls 1-250, 251-500, 501-750, or 751-1000+ students per year.

13. There will be no difference in the choice of behavioral objectives by instructors whose department offers a graduate program in biology and those whose departments do not have a graduate program.

14. There will be no difference in the choice of behavioral objectives by instructors who also teach a graduate level course and those who do not teach a graduate level course.

The alternate hypotheses will all be two-tailed and the level of significance upon which to base the decision to reject the null hypotheses will be set at the .05 level.

The Chi-square test for Two Independent Samples and the Chi-square for K Independent Samples (Siegel, 1956), non-parametric statistical tests, will be used to test the hypotheses.

Limitations of the Study

This study will be limited to those instructors in the institutions of higher education in Missouri, who have some responsibility for the non-major general biology course who return the questionnaire and to the correctness of their responses.

The goals chosen could not reflect every factor which influences the curriculum, the instructor, or the institution. Those variables chosen might not be the most important.

The behavioral objectives chosen to reflect these goals might not reflect the actual intent, depth, or breadth of the goal.

CHAPTER II

REVIEW OF THE LITERATURE

Downing (1925) reviewed a number of investigations made with regard to the relative merits of the lecture-demonstration and the laboratory methods of instruction. The investigations of Wiley (1918), Cunningham (1920), Phillips (1920), Cooprider (1922), Kiebler and Woody (1923), Cooprider (1923), Cunningham (1924), and Anibal (1924) were all done with high school groups. In a summary of the conclusions of these investigations Downing states:

> The lecture demonstration method of instruction yields better results than the laboratory method in imparting essential knowledge and is more economical of time and expense. This is true for both bright and dull pupils and for all type of experiments. . . .
>
> The lecture-demonstration method appears to be the better method for imparting skill in laboratory technique in its initial stages and for developing ability to solve new problems.
>
> Oral instructions are, in general, more effective than written instructions in lecture demonstration but less effective in laboratory work.
>
> 'What the experiment proves' is the item on which more pupils fail and is evidently the point to be stressed in teaching.

Hurd (1929) reviewed, in addition to those studies reviewed by Downing, the work of Hunter (1921), Carpenter (1925), Johnson (1926), Knox (1927), Reidel (1927), Duel (1927), and Nash and Phillips (1927), all of which were related to secondary school science.

The general conclusions to be gained from these studies would indicate that: (1) The demonstration is equal to the laboratory method, judged by the methods used. (2) One student working on an experiment is better than two, though the difference is not great. (3) The intelligent student succeeds no matter what the method. (4) Students lower in intelligence seem to do better with the demonstration method. (5) Achievement in general is higher with higher intelligence.

Hurd (1929) also reviewed what were the first investigations of methods at the college level, Colton (1925), Bane (1923), Noll (1926), and Scheidemann (1927).

The general conclusions to be drawn from these works are: (1) There is no difference in gains of intensive laboratory work for training and extensive laboratory work for information. (2) The lecture and class discussion methods of college teaching appear about equally effective in the immediate recall of content material. (3) The class discussion is more effective than the lecture in delayed recall. (4) The lecture method is more suitable for immediate recall of subject matter than for its retention to a later period, while the reverse is true of the class discussion method. (5) When two groups, which were almost identical in every respect, except in the amount of laboratory work, the group having the more laboratory work showed some superiority in general achievement.

Hurd (1929) in the 1926-27 school year circulated a questionnaire among the teachers of science at the University of Michigan in an attempt to determine what each teacher believed to be the particular function of the laboratory in instruction in science. This pioneering work illustrates the variety and confusion of opinion that existed at that time as to the objectives in laboratory work.

Function of the Laboratory in Science

1. Actual practice in the performance of operations in the field of the subject 8
2. To develop the technique of the subject 8
3. To develop manipulative skill 7
4. First-hand contact for acquaintance 7
5. Makes ideas realistic or concrete 5
6. Develops interest 4
7. To aid memory 4
8. Application of principles 4
9. For demonstration 3
10. To give the scientific manner of thought and training in drawing conclusions 3
11. Gives opportunity for developing sense perception and acquisition of concepts 3
12. Develops powers of observation 3
13. For illustration 2
14. Develops ability to do independent work 2
15. Instructs by making visual impressions 2
16. Gives a chance for student initiative 2
17. Gives accurate concepts 1
18. Clarifies the textbook 1
19. Supplements the text in clarifying principles 1
20. Repetition by concrete contact 1
21. Teaches correct proportions and proper arrangement of the parts 1

22. Furnishes experience on which to base reasoning . . . 1

23. Coordinates theories and facts by interpretation of observations 1

24. Teaches a student self-confidence 1

25. Develops an inquiring mind 1

26. Develops the quantitative and experimental viewpoint 1

27. Develops ability to obtain and evaluate first-hand information 1

28. Develops ability to discard the immaterial 1

29. To show a method of ascertaining facts and answering questions 1

30. To create confidence in the text 1

31. To provoke thought 1

32. To suggest problems 1

33. To give opportunity for developing inventive ability 1

34. To show the difficulty of generalization 1

35. First-hand acquaintance with the experimental side 1

36. Overcomes disgust (animal dissection) 1

37. Develops self-control 1

38. Trains a student in planning, in care, accuracy, and the use of data and weighing of evidence 1

39. Shows a student whether he is really interested in, or properly prepared for, scientific laboratory work 1

40. Gives opportunity for analysis and comparison 1

41. Develops synthetic ability 1

42. To get a thorough and systematic knowledge 1

43. Makes the student study the text in order to write up the experiments 1

In addition to this list Hurd also asked a number of high school science teachers enrolled in the University of Chicago during the summer of 1927 what they believed they had received from certain courses pursued by them in science.

Abilities Developed by Laboratory Work

		Frequency of Statement
1.	Manipulation	20
2.	Thinking through problematic situations	12
3.	Independent work	6
4.	Following instructions carefully	6
5.	Logical methods of recording data	6
6.	Facility or accuracy in measurement	6
7.	Ability to understand fundamental principles and facts	5
8.	Gather materials together for carrying through problems	4
9.	Observation of detail	4
10.	Thinking in quantitative terms	3
11.	Ability to keep a fairly good notebook	3
12.	Ability to cooperate with others	3
13.	Accuracy in getting data	2
14.	Ability to waste time	2
15.	Ability to work carefully	2
16.	Scientific method	2
17.	Verify textbook material	2
18.	Ability to systematize	2
19.	Enthusiasm	2

20. Habits of accuracy, patience, etc. 2

21. Skill in technique 2

22. Gain confidence 1

23. Devise new ways 1

24. Appreciation of others' work 1

25. Helped me to choose my vocation 1

26. Knowledge of electrical devices 1

27. Emotional serenity 1

28. Accuracy in drawing conclusions 1

29. Ability to express ideas 1

30. Honesty 1

31. Ability to picture theory actually working 1

32. Ability to see relations 1

33. Critical attitude 1

34. Persistence 1

35. Interpretation of printed instructions 1

It is interesting to note that about 37 per cent of these teachers felt that these outcomes could have been developed by some procedure other than laboratory work and about 85 per cent that time was wasted.

Noll (1932) states:

> To make an all inclusive or general statement of the aims and objectives of college science teaching is very difficult, if not impossible . . . consider the aims of college curricula and courses, and more specifically, college science courses from this point of view. At least three broad types of functions are at once evident; first the cultural or liberal education, second, the teacher training, and third, the highly specialized or technical. . . . In the attempt to fulfill these functions, courses of all varieties have been developed, from the most specialized and technical to the most general.

> There is very little evidence, however, to show that the courses have been developed with any difference of functions or aims in mind. We find, at least in beginning courses in college science, that students of all types and with all possible variety of purposes in mind, are herded together in the same introductory courses. . . .
>
> Whatever the methods used in obtaining an agreement upon aims, the important fact is that, so far as the writer is aware, no organized attempt to do this for college science courses has ever been made.
>
> What has been said . . . regarding aims of college science courses applied particularly to the beginning, or introductory, type of course.

Beauchamp (1933), after studying the courses of study of 160 different courses from twenty-six states, found the following objectives to have been stated.

An Analysis of the Objectives Listed in

Courses of Study in Science

Types of Objectives

A. Knowledge

1. To acquire information about science
2. To acquire knowledge which will produce a better understanding of our environment
3. To acquire the knowledge necessary to correct superstition and erroneous beliefs
4. To acquire a scientific vocabulary
5. To acquaint the student with the source of scientific knowledge
6. To acquire information concerning the lives of the great men of science
7. To acquire a body of facts which will enable one to read scientific literature
8. To acquire a knowledge of the fundamental principles of the subject
9. To acquire a knowledge of the application of principles to industry
10. To acquire the knowledge necessary for future courses in science or to prepare for college
11. To acquire knowledge to increase the general culture of an individual
12. To meet the demands of the State departments

13. To acquire knowledge which will function to secure the objectives stated in the bulletin on Cardinal Principles of Secondary Education--
    (a) Health
    (b) Command of fundamental processes
    (c) Citizenship
    (d) Worthy home membership
    (e) Vocation
    (f) Worthy use of leisure time
    (g) Development of ethical character

B. Exploration (or orientation)

1. To give the pupil a view of the field of science so that he may explore his interests, capacities, and abilities
    (a) As a basis for the election of further courses in science
    (b) As a basis for the selection of a vocation
    (c) To acquire new fields of interest

C. Abilities

1. To develop the ability to think scientifically
    (a) To develop reliance on facts
    (b) To develop the power of interpretation
    (c) To develop the power of observation
    (d) To develop the ability to form independent judgments
    (e) To develop the ability to evaluate
    (f) To develop the ability to generalize
    (g) To develop the ability to locate problems
    (h) To develop the ability to plan prior to execution
    (i) To develop the ability to gather data systematically
    (j) To develop the ability to recognize defects and errors in conditions and processes
    (k) To develop the ability to do quantitative thinking
    (l) To develop the ability to express ideas in clear and coherent English
2. To develop the ability to use the scientific instruments common in the laboratory

D. Attitudes

1. To develop a scientific attitude as shown by ability--
    (a) To view facts objectively
    (b) To be free from dogma and superstition
    (c) To hold one's conclusion as tentative and to suspend judgment until facts are secured
    (d) To revise one's opinions if the evidence warrants

(e) To have a spirit of inquiry
(f) To be open-minded
(g) To have a conviction of the universality of the cause and effect relationship

2. To develop attitudes of appreciation of--
    (a) The contributions of scientific method
    (b) The contributions of science to mankind
    (c) The great men of science
    (d) Expert judgment
    (e) Nature
    (f) One's responsibility in the world
    (g) Natural laws
    (h) The importance of quantitative thinking
    (i) The importance of original research

E. Ideals and habits

1. To acquire ideals or habits of accuracy, persistence, honesty, self-control, truth, etc.
2. To inculcate a safe, sane, reverent attitude toward science
3. To evolve high standards of conduct in personal and group life

F. Interests

1. To acquire an appetite for investigations in science
2. To acquire an appetite for scientific reading
3. To acquire an interest in taking more science
4. To acquire an interest in nature
5. To acquire interests in vocational fields
6. To acquire wholesome interests which may be used to enjoy spare time

Smith (1935) reporting for the Committee on Tests of the Division of Chemical Education of the American Chemical Society provides a list of objectives for the introductory chemistry course as obtained from a questionnaire answered by chemistry teachers from 57 land grand colleges, 41 universities, 57 colleges, and 30 authors of college and high school chemistry texts states:

> With the exception of a knowledge of natural laws and important principles, the questionnaire implies nothing as to the subject matter content of the course.
>
> . . . The attention of the committee was directed toward other objectives, in reality, more important. It was thought that it is not primarily the mastery of specific subject

matter but the ability to meet situations and to solve them that constitutes the more valuable training the student receives.

I. To provide pupils with a broad and genuine appreciation and understanding
   (a) of the world in which they live
   (b) of what the developments of chemistry mean in modern social life
   (c) in industry
   (d) in national life
   (e) of the work of recognized experts or scientists
   (f) of the actual or possible economic significance of new chemical discoveries
   (g) new material of commerce
   (h) new knowledge
   (i) of the cost of the acquisition of new knowledge in money
   (j) in labor
   (k) in human lives

II. To provide opportunity for the acquisition of knowledge alone
   A.(a) of natural laws
   (b) of the significance of cause and effect
   (c) of important facts
   (d) in the ability to draw generalizations from specific experimental data
   (e) in the ability to test a proposal by hypothesis by planning experiments that might be used
   (f) in the ability to locate chemical information in a library
   B.(a) To provide an opportunity to acquire skill in the manipulation of laboratory equipment

III. To provide an opportunity for training
   (a) in the scientific method of thinking (assuming that this is being done) through the study of chemical problems
   (b) (in your opinion, is this being done?) Yes
   (c) in the explaining of natural phenomena to the end that science and reality may function in place of superstition and uncertainty
   (d) in the ability to apply important principles of chemistry
   (e) to provide an opportunity to acquire (essentials to the study of science)
      (1) specific ideals
      (2) habits of thought and action
      (3) desire for achievement
      (4) initiative
      (5) persistency
      (6) open-mindedness
      (7) honesty

IV. To provide an opportunity for the pupil to satisfy his natural curiosity
   (a) in the things and forces of nature
   (b) to gain information which is interesting purely for its own sake
   (c) to indulge in the manipulation of chemical material in order that he may explore, as he desires, the world of reality

V. To provide opportunity
   (a) for gaining chemical knowledge which will contribute to individual health
   (b) for the pupil to become acquainted with some of the applications of chemistry to home and community life, to commerce, trades, and the professions in connection with pure foods, elimination and utilization of wastes, public utilities, health regulations, etc., with the object of good citizenship.

VI. To provide an opportunity for the pupil to determine his interests in chemistry and in the opportunities in this field (to the end that the pupil may come to a decision as to whether chemistry offers him a field for vocational activity)

VII. To provide interests which may function in
   (a) more worthy use of leisure time
   (b) in ability to read more intelligently and with greater interest articles pertaining to chemistry and scientific books

Considering a return of sixty-six percent to indicate that the proposed objective was generally accepted the following summary was presented:

I. A study of chemistry should provide the individual with a broad and genuine appreciation and understanding of the chemical aspects of the universe; of the place of chemistry among the sciences; and of what the developments in chemistry mean in modern social and industrial life (good citizenship).

II. A study of chemistry should provide an opportunity for the acquisition: of experiences in the use and the knowledge of the scientific method of thinking, using chemical problems; of a knowledge of natural laws, important principles and facts; of the ability to draw generalizations from specific experimental data and to apply important principles; and of some skill in laboratory manipulation.

III. A study of chemistry should provide an opportunity for the individual to determine his interests and aptitudes in chemistry as a vocation.

Carmody (1935) classified the objectives of elementary laboratory instruction as follows:

To furnish to students opportunity to:
1. Develop interest in experimental work.
2. Develop training in the logical or 'scientific' method of experimentation and thinking.
3. Develop facility with and appreciation of or feeling for laboratory experimentation.
4. Develop knowledge of and familiarity with substances and phenomena by first-hand study.

Carmody states further:

> Educational principles are grossly neglected when the 'object' of an experiment, as far as the student can make out, is to obtain a certain answer or a certain laboratory result. A title such as 'To Determine the Atomic Weight of Copper' certainly does not express the true object of the experiment. Can one wonder that the answer alone becomes the important objective in the mind of the student.
>
> On the other hand, a stated object such as 'To Study the Principles of Atomic Weight Determination and To Develop Technique in Accurate Quantitative Experimentation' serves to impress on the student the true objective and what he might expect to obtain of permanent value from the performance of the experiment. It indicates to the student that the most important part of elementary experimentation is the development of method (the method of thinking and the method of doing) and the ideas acquired; in a word, that the change occurring within the mind and body of the student, not within the test tube, is important . . . an experiment should be selected and designed to accomplish one objective only. . . . Experiments involving complex or uncertain objectives and numerous others more adaptable to lecture demonstration than to individual laboratory work should not be included. . . . According to the objective desired, experiments may be classified into three types: (1) to furnish training in logical methods, (2) to develop laboratory technique, and (3) to develop knowledge of chemical phenomena.

Schlesinger (1935) states that evidently most of the teachers of high school and general chemistry hold the following as their aims:

(1) To illustrate and clarify principles discussed in the classroom, by providing actual contact with materials.
(2) To give the student a feeling of the reality of science by an encounter with phenomena which otherwise might be to him no more than words.

(3) To make the facts of science easy enough to learn and impressive enough to remember.
(4) To give the student some insight into basic scientific laboratory methods, to let him use his hands, and to train him in their use.

and that of those teachers who did favor laboratory did so because "laboratory experience fixes facts and principles in the minds of students, increases their interest and enthusiasm, and helps them to obtain a more rapid understanding."

Schlesinger does not, however, believe these to be the most important aims as he states:

> . . . in planning laboratory courses, it is essential to keep in sight the major objectives--training in observation, in thought, and in action. Although the illustration of principles and the clarification of difficulties by direct contact with the phenomena cannot be neglected, the main purpose must be achieved by selecting as the most significant part of the laboratory work, exercises the results of which the student cannot readily predict. These exercises should, as far as possible, demand the solution of some simple problem, by experimental means. Successful work should require increasing accuracy of observation, increasing ability to use data and knowledge in drawing conclusions, and increasing independence in planning tests to check the conclusions drawn.

Leighton (1935) presents a list of objectives as judged by twenty science faculty members of the University of Oregon as follows:

Analysis of Laboratory Objectives in Terms

of Functions of the Lower Division

I. Social Intelligence Curricula Functions

1. Those Related to the Effectiveness of Teaching
   a. To teach more completely by concretizing the material, thereby increasing the number of senses through which the pupil learns
   b. To increase the time of retention of subject matter
   c. To give concepts rather than definitions
   d. To develop an understanding of the organization of knowledge

e. To develop an appreciation of the order and unity in the universe
f. To help the student understand moderately technical books, papers, and lectures

2. Those Related to Personality Traits
   a. To develop self-reliance
   b. To develop initiative
   c. To develop good judgment
   d. To teach the student to distinguish between verified conclusions and assumptions

3. Those Related to the Acquisition of Skills
   a. To teach appreciation of skill in problem solving
   b. To teach laboratory technique which will enable the student to pursue some phase of pure or applied science as an avocation
   c. To teach the technique of general experimentation and manipulation
   d. To teach the student the value of a scientific vocabulary for concise expression
   e. To teach the student to visualize natural laws

4. Those Related to the Scientific Attitude
   a. To develop an intelligent interest in scientific advancement
   b. To teach accuracy in thought as well as in measurement
   c. To teach the student to verify results
   d. To teach powers of observation
   e. To teach caution in forming conclusions
   f. To show the difficulty of generalizations
   g. To teach skill in distinguishing essentials from non-essentials
   h. To develop ability to think through a problem and arrive at logical conclusions
   i. To develop the ability to organize knowledge
   j. To develop the value of selecting and evaluating first-hand information
   k. To give first-hand acquaintance with experimental data and procedure
   l. To create confidence in established facts

5. Those Related to Motivation
   a. To increase the student's range of interests
   b. To relate the subject matter to real life
   c. To stimulate the spirit of investigation

6. Miscellaneous
   a. To provoke thought
   b. To make possible more intimate contact between the teacher and pupil

c. To show the student whether he is really interested in or properly prepared for laboratory work

Seashore (1935) presents a list of objectives for lecture and laboratory work in a course in general psychology. It is interesting that the list was, with modifications, directly transposable from a course in geology.

I. Objectives common to all sciences as they apply to psychology.

A. In terms of attitudes.
  1. To develop a breadth of appreciation in considering new fields of interest and viewpoints in the pursuit of knowledge (desirable, but not necessarily certain outcomes of a course).
    a. To arouse intellectual curiosity about the forces underlying human behavior.
    b. To appreciate man's place in the universe and the universality of physical laws.
    c. To secure a long-range view of the development of human activities through the evolutionary and comparative approaches.
    d. To view psychology as a basis for understanding the behavior of people in everyday life.
    e. To develop an understanding of individual differences in 'natural resources' (especially one's own make-up or 'personality') in order to more intelligently utilize them.
    f. To build up the intellectual foundation for more discriminating and complete aesthetic responses to natural phenomena.
  2. To develop an appreciation of the value of the scientific method in the field of psychology. (May also be <u>directly</u> connected up with other fields but usually not much transfer, unless approached with that in view.)
  3. Orientation.
    a. To discover or develop interest in science or non-science fields, and if in science perhaps in a specific field, thus assisting in the selection of future studies or careers.

B. In terms of information.
  1. To acquire a foundational knowledge upon which to build for later studies.
    a. A basic knowledge of sensory, motor, effective, and intellectual aspects of behavior.
      (1) In terms of 'experience' or performance
      (2) In terms of component receptor, connector, and effector processes, and environmental relationships.

b. An understanding of the principles of such dominant psychological processes as (1) perception, (2) attention, (3) learning, (4) memory, (5) thinking, (6) imagination, (7) emotion, (8) skilled performances, etc.

C. In terms of skills
  1. To develop the techniques (instruments or methods) of obtaining psychological data.
  2. To develop the abilities to
     a. Formulate psychological hypotheses.
     b. Rigorously criticize hypotheses (including reading of experiments).
     c. Systematically test the hypotheses.
     d. Draw conclusions.

Seashore also presents a list of general principles or attitudes which he feels are prerequisite to, or a part of, the scientific method.

> Attitudes may be thought of as general orientation or proneness to adopt certain approaches to various situations.
>
> 1. Open-minded willingness to investigate any problem by the objective (impersonal) method wherever necessary. Likewise, a corresponding willingness to change a point of view if further data warrants reconsideration.
> 2. The recognition of many alternative explanations and the corresponding necessity for suspension of judgment until all critical angles have been investigated. It must be pointed out, however, that temporarily a scientist may with perfect propriety attempt to push any one working hypothesis to an extreme in order to give it a most critical test. Over a longer period of time this will include the investigation of all of the important hypotheses in a situation, either by the same investigator or by others working on the problem.
> 3. 'Intellectual curiosity': wide-spread use of careful observation in search for significant interrelations with other phenomena, an interest in knowledge for its own sake, which in later stages becomes relatively independent of outside motivations.
> 4. Recognition of the value of the long range (pure science) point of view as the basic program for the advancement of knowledge. Scientific method is equally applicable to immediately practicable situations, but these are usually dependent upon the existence upon a large body of general knowledge from the pure fields.
> 5. A clear recognition and labelling as such of assumptions, hypotheses, and theories, as distinguished from established facts or principles.
> 6. A critical, analytical approach, demanding proof for assertions. Speculation as to basic explanations usually leads to an experimental investigation and

checking of hypotheses rather than continued deductive reasoning. A fertile imagination in forming hypotheses, but great caution in drawing conclusions.

7. Systematic procedures, implying logic and statistics, as well as the experimental method in seeking to reduce everything to a quantitative basis. (Does not neglect simple descriptions, but endeavors to keep all descriptions on a translatable basis, referable to fundamental descriptions of other sciences.)
8. Straightforward approach, analyzing problems and avoiding confusing side-issues or other matters of superficial interest.
9. Care in drawing conclusions.
   a. Limiting conclusions to data at hand.
   b. Recognizing the possibility of and guarding against sources of error such as prejudice, insufficient evidence, neglect of negative instances, selected or unrepresentative examples, effects of chance, forgetting, unreliability of testimony, gaps in reasoning, parallel but non-causal relationships, etc.
   c. Recognizing the probability of partial relationships in multi-causal situations and of degrees of relationships, rather all-or-none cases.
   d. Avoidance of spurious appearances of accuracy, such as many decimal places on figures where other factors in the situation render such accuracy unimportant.
10. Emphasis upon integrity of work as a guarantee of accuracy, and in recognition of the status of science granted by society in willingness to wait for long-time results rather than demanding immediate results as in most professions. (The pertinence of the phrase 'The truth, the whole truth, and nothing but the truth' indicates the parallel relation between science and the law, in attempting to secure accurate information as a basis for logical decision: Likewise, in constantly seeking to avoid any factors which might prejudice interpretation.)
11. A recognition of the appropriateness of scientific attitudes in certain situations and other attitudes, for instance, social, esthetic, etc., various types of attitudes should theoretically form parts of a consistent philosophy.
12. A recognition of one's fallibility outside of his own special field of study, and a consequent evaluation of statements according to the competence of persons to speak on various topics.

Noll (1935) states:

It seemed logical and justifiable to proceed with the analysis of the scientific attitude on these assumptions: first, that the scientific attitude, and attitudes in general, are based upon habits, in this case, habits of thinking; second, that the scientific attitude can be described in terms of habits of thinking; third, that such habits can be developed and measured.

He then submits what he feels to be those habits of thinking which are part of the scientific attitude:

(1) Habit of accuracy in all operations, including accuracy in calculation, observations, and report.
(2) Habit of intellectual honesty.
(3) Habit of openmindedness.
(4) Habit of suspended judgment.
(5) Habit of looking for true cause and effect relationships.
(6) Habit of criticalness, including that of self-criticism.

and further clarifies the habits with the following illustrations:

(1) Accuracy in calculation, observation, and report is the opposite of habits of careless, inaccurate work.
(2) Intellectual honesty is the opposite of such habits as exaggeration and rationalization.
(3) Openmindedness is the opposite of bigotry, prejudice, and intolerance.
(4) Suspended judgment is the opposite of the habit of making snap judgments, or of jumping to conclusions.
(5) Looking for true cause and effect relationships is the opposite of habits of superstitious thinking, of expecting rewards to come without commensurate effort.
(6) The habit of criticalness, including that of self-criticism, is the opposite of habits of accepting explanations of phenomena without question, or without attempt at evaluation; it is the opposite of the habit of condoning and accepting such things as racketeering, political corruption, and the like, as inevitable.

Crowell (1937) developed a list of scientific skills and scientific attitudes considered to be part of the scientific method. These were submitted to sixty-four individuals in forty-nine institutions from twenty states for evaluation. Those skills and attitudes accepted by 80 percent of the respondees are listed.

Attitudes

One must revise one's opinion if the evidence warrants.

One must be careful and accurate in what one does.

One's judgments must be as unprejudiced and impersonal as is possible.

Nothing can happen without a cause.

It is necessary to be systematic in the gathering and recording of data.

One must hold one's conclusions as tentative and suspend judgment until all available facts are secured.

Theories are often valuable because of the experiments to which they lead, even though they themselves are later disproved.

One must be slow to accept as fact such statements as are not supported by convincing proof.

One must view facts objectively.

One must be free from dogma and superstition.

The adequacy and appropriateness of one's data can be decided upon only as a result of careful reasoning.

One should rely on facts.

Man's conception of truth changes.

It is necessary to plan prior to execution.

One must recognize that all data are not of equal value.

One must test all hypotheses against all available data.

Skills

Skill in observing accurately.

Skill in recording observations accurately and orderly.

Skill in forming independent judgments based on facts.

Skill in distinguishing between fact and theory.

Skill in picking out pertinent elements from a complex situation.

Skill in recognizing errors and defects in conditions and processes.

Skill in evaluating conclusions in the light of facts or observations on which they are based.

Skill in isolating the experimental factor.

Skill in forming sound judgments concerning adequacy of data.

Skill in synthesizing or putting together separate facts to form a conclusion.

Skill in gathering data systematically.

Skill in planning an experiment to determine whether or not a proposed hypothesis is true.

Skill in evaluating data or procedures.

Skill in recognizing omissions or deficiencies in situations.

Skill in profiting from worth-while criticism.

Skill in forming a reasonable generalization.

Skill in arranging and classifying data in sequence and making conclusions obvious.

Skill in applying general principles to new and concrete situations.

Ebel (1938) states:

Thus, while the scientific attitude and the scientific method are definitely related, they are by no means identical.

On the basis of these definitions of attitude and scientific, the following test for the suggestions relating to the scientific attitude was set up.

1. Can the thing suggested be a mental set?
2. Can the thing suggested affect a variety of stimuli?
3. Can the thing suggested condition the mind to a certain type of response?
4. Can the thing suggested become stabilized?
5. Can the thing suggested foster scientific achievement, which includes:
   a. Additions to the world's store of organized truth.
   b. Addition to the individual's store of organized truth.
   c. Use of organized truth as a basis for determining action?

Using these tests, Ebel tested various statements against them and presents the following list of elements of the scientific attitude:

The scientific attitude includes:

I. Readiness to be confident that human intelligence can understand the phenomena of nature, and through that understanding can become able to control the forces of life. This element of the scientific attitude
   A. Consists of
      1. Readiness to be confident that natural phenomena are understandable, which involves
         a. Readiness to be confident that the universe is a self-sustaining unit which includes
            1) Readiness to believe that there is no supernatural interference in the universe
            2) Readiness to believe that even man is a natural phenomenon
         b. Readiness to be confident that these are orderly interrelations between all natural phenomena, which includes
            1) Readiness to believe that there are reasons for all things, including
               a) Readiness to believe that every event has a natural cause
               b) Readiness to believe that the same cause always produces the same effect
               c) Readiness to believe that consequences can be deduced from or explained in terms of their antecedents
            2) Readiness to believe that recurring sequences of cause and effect indicate permanent general relations which may be formulated as natural laws, involving
               a) Readiness to believe that the truth itself does not change although our ideas of it may change
               b) Readiness to believe that these laws may be used to accurately predict future occurrences of natural phenomena
         c. Readiness to be confident that these various relations indicate a systematic unity in natural phenomena
      2. Readiness to be confident that human intelligence is capable of understanding natural phenomena, which involves
         a. Readiness to have confidence in sensory data, which includes
            1) Readiness to believe that the world of common sense experience cannot be transcended
            2) Readiness to believe that the objective evidence obtained by observation of the external world is the only dependable source of truth

        b. Readiness to have confidence in human reasoning
    3. Readiness to be confident that this understanding will enable man to gain increasing ability to adjust himself to the forces that affect life, and to gain increasing control over those forces

B. Gives rise to
    1. Readiness to discredit and abandon all beliefs which depend upon supernatural interference or the suspension of natural law, which involves
        a. Readiness to discredit and abandon superstitious beliefs
        b. Readiness to discredit and abandon beliefs in miraculous occurrences
        c. Readiness to discredit and abandon belief in the possibility of getting something for nothing
        d. Readiness to discredit and abandon belief in the innate authority of hunches, first impressions, feelings, etc.
    2. Readiness to accept tested human knowledge
    3. Readiness to deny the possibility of danger in flooding the world with too much knowledge
    4. Readiness to seek personally to understand the phenomena of nature, which involves
        a. Readiness to seek a unified, orderly comprehension of natural phenomena
        b. Readiness to rely ultimately upon individual thinking and independent judgment
    5. Readiness to attack problems with reason, which involves
        a. Readiness to think freely, defying all dogmas, precedents, authoritative dicta and traditions which are not based on reason
        b. Readiness to seek truth through observation, experiments and thinking
        c. Readiness to look for true cause and effect relations
        d. Readiness to use imagination constructively to suggest a variety of hypothetical solutions to a problem
        e. Readiness to test the hypotheses in the hope of developing dependable laws which will solve not only the immediately problem but also other problems of a like nature
    6. Readiness to deny that the status quo of the trend of events are inevitable
    7. Readiness to seek to control human action with persuasion, not with force

II. Readiness to seek true understanding of the phenomena of nature. This element of the scientific attitude
   A. Arises from
      1. Readiness to love knowledge for its own sake
      2. Readiness to be devoted to social service, which involves
         a. Readiness to desire improvement in the status quo
         b. Readiness to seek increasing control over the forces of life, not for the private exploitation of other humans, but for the progressive advancement of social welfare
      3. Readiness to seek personal achievement
   B. Gives rise,
      1. In relation to the phenomena of nature in general, to
         a. Readiness to have broad and versatile interests
         b. Readiness to be sensitively curious
         c. Readiness to attempt the discovery of new knowledge
      2. In relation to specific problems, to
         a. Readiness to make an active attack on the problem
         b. Readiness to be industrious, persistent and relentless in the search for truth
         c. Readiness to overcome obstacles to the discovery of truth, which involves
            1) Readiness to face personal danger in the pursuit of truth with a courageous, adventurous spirit
            2) Readiness to defy intolerance, to cast off restrictions and to think freely in the pursuit of truth
            3) Readiness to sacrifice personal interest in profit, reputation, or even life itself, with an unselfish, heroic devotion to truth
            4) Readiness to disregard any unpleasantness of conditions, processes or conclusions in searching for truth
            5) Readiness to ignore the apparent uselessness of the truth being sought, and to ignore the lack of assured material reward for its discovery
         d. Readiness to attempt to improve the methods of obtaining truth
         e. Readiness to record and openly publish all discoveries and developments so that they may make an unselfish contribution to scientific advancement and social progress

3. In relation to scientific achievements, to
    a. Readiness to consider the disclosure of truth to be the greatest of all achievements
    b. Readiness to respect and admire those who have contributed to the disclosure of truth

III. Readiness to seek corrections in work and thinking so that the truth may be discovered. This element of the scientific attitude includes
  A. Readiness to seek specific training for any observing, experimenting, thinking, or other operation necessary to the discovery of truth.
  B. Readiness to seek a factual basis for all conclusions, and to avoid assertion. This involves
    1. Readiness to distinguish between facts, which correspond to objective reality, and fancies
    2. Readiness to investigate and gather evidence, which includes
        a. Readiness to observe and to experiment
        b. Readiness to read reports of similar investigations to acquire the data that others have gathered
        c. Readiness to recall pertinent information out of all previous experience
    3. Readiness to examine and compare the data, which includes
        a. Readiness to pick out essential elements in the data
        b. Readiness to discover similarities, dissimilarities and exceptions in the data
        c. Readiness to determine what conclusions may be derived from the data
  C. Readiness to be carefully and painstakingly accurate in all work and thinking, which involves
    1. Readiness to define the problem
    2. Readiness to observe accurately, which includes
        a. Readiness to control the conditions under which observation takes place, including
            1) Readiness to isolate the facts to be observed, removing irrelevant objects and distractions
            2) Readiness to avoid complexity and brevity in the events observed
        b. Readiness to observe minutely
        c. Readiness to use mechanical aids to extend the range of observation
        d. Readiness to use measuring instruments to improve the precision of observation
    3. Readiness to experiment accurately, which includes

- a. Readiness to plan and execute the experiment rigorously and carefully
- b. Readiness to control all conditions
- c. Readiness to permit only one variable
- d. Readiness to use control experiments

4. Readiness to think accurately, which includes
   - a. Readiness to think logically, involving
     - 1) Readiness to use sound, pertinent and adequate data in making inductions
     - 2) Readiness to follow rules of logic in making deductions
   - b. Readiness to think objectively, which involves
     - 1) Readiness to avoid rationalization
     - 2) Readiness to avoid wishful thinking
   - c. Readiness to think deeply, which involves
     - 1) Readiness to penetrate external appearances
     - 2) Readiness to avoid basing conclusions on coincidences
     - 3) Readiness to avoid basing conclusions on superficial analogy
   - d. Readiness to think coldly, which involves
     - 1) Readiness to be impersonal and disinterested in thinking
     - 2) Readiness to be unemotional, dispassionate and thoroughly self-controlled in thinking
     - 3) Readiness to control imagination
     - 4) Readiness to avoid being swayed by oratory
     - 5) Readiness to avoid being swayed by the mere novelty or sensationalism of an idea
5. Readiness to calculate accurately
6. Readiness to use words accurately, which involves
   - a. Readiness to read carefully
   - b. Readiness to choose words carefully
   - c. Readiness to define all terms
7. Readiness to be accurate in statement, which involves
   - a. Readiness to avoid assertion
   - b. Readiness to avoid exaggeration
   - c. Readiness to be explicit, not vague
   - d. Readiness to use quantitative expression
8. Readiness to record procedures and results to eliminate the inexactness of memory

D. Readiness to be orderly in all work and thinking, which involves

1. Readiness to be systematic in attacking a problem, in observation, and in examination of data
2. Readiness to organize data and arrange it cogently

E. Readiness to seek completeness in all work and thinking, which involves
   1. Readiness to seek all the facts, which includes
      a. Readiness to observe and experiment extensively and under a variety of conditions
      b. Readiness to read widely
   2. Readiness to consider all possible hypotheses
   3. Readiness to keep alert for and listen to any suggestions for further observation, experiment, reading or thinking
   4. Readiness to persist until an adequate explanation has been discovered, or the whole truth made clear
F. Readiness to avoid needless complexity in conclusions, which involves
   1. Readiness to favor the simplest explanation of a phenomenon
   2. Readiness to favor the most fruitful hypothesis which, having widest application, relates the greatest number of facts to each other
G. Readiness to be openminded, which involves
   1. Readiness to recognize valid new conceptions, regardless of their conflict with tradition
   2. Readiness to prevent any doctrine from becoming a master to thinking
H. Readiness to be intellectually honest, which involves
   1. Readiness to eliminate prejudices, bigotry and bias
   2. Readiness to be convinced by the evidence, which involves
      a. Readiness to admit error when it becomes apparent
      b. Readiness to abandon pet hypotheses
      c. Readiness to change opinion on the basis of new evidence
   3. Readiness to recognize the limits of accuracy, probability of correctness, and significance of all conclusions, including scientific conclusions
   4. Readiness to be humble, which involves
      a. Readiness to recognize the contributions of others
      b. Readiness to recognize the relative insignificance of present accomplishments in comparison with the tremendous work remaining
I. Readiness to check and verify all work and thinking, which involves
   1. Readiness to verify observations, experiments and thinking by repetition and comparison
   2. Readiness to verify deductions by checking them in terms of the rules of logic

3. Readiness to test hypotheses by applying them to the facts
4. Readiness to test theories by making predictions on the basis of them and comparing the predicted result with the observed result
5. Readiness to record and openly publish all discoveries and developments so that they may be checked by others

J. Readiness to suspend judgment until all facts are in and have been considered, which involves
1. Readiness to refuse snap judgments and hasty generalization
2. Readiness to deliberately reflect on the facts
3. Readiness to be active but patient in attempting to arrive at judgments, neither expecting nor demanding immediate success in attempts to discover truth
4. Readiness to tolerate and respect another's point of view, pending suitable investigation
5. Readiness to recognize the tentativeness of all conclusions, including scientific conclusions
6. Readiness to hold opinions tentatively

K. Readiness to be critical of all work and thinking, which involves
1. Readiness to examine all work and thinking to see if it has the characteristics of scientific correctness (see section III, divisions A to J above)
2. Readiness to extend the attitude of criticalness so that it includes self-criticism

L. Readiness to be rationally and impartially skeptical of the products of human work and thinking, which involves
1. Readiness to be cautious and conservative in accepting conclusions
2. Readiness to avoid gullibility and overcredulity

Adams (1942), reporting the results of a survey of 94 institutions in 38 states regarding the objectives of instruction in the laboratory, supplies the following:

Chemistry laboratory instruction should:
(a) develop the ability to make observations, interpret and draw conclusions from observed facts,
(b) develop the ability to use simple scientific instruments and manipulate apparatus,
(c) develop the ability to keep a record and write a satisfactory report,
(d) develop the attitude of drawing conclusions only from observable or accepted data,

(e) develop the habits of accuracy, honesty, self-reliance, cleanliness, and orderliness in the laboratory,
(f) satisfy the students' curiosity and provide experience to develop latent interests,
(g) provide opportunity for instruction.

Keeslar (1945), citing the work of Downing (1928), Weller (1933), Curtis (1934), and Crowell (1937), developed an original list of the elements of scientific method, which were then submitted for evaluation to twenty-two research scientists at the University of Michigan. Keeslar's list is as follows:

I. Sensing a problem and deciding to try to find the answer to it
II. Defining the problem
  Stating the problem in words
  Analyzing the problem into its essential factors
III. Studying the situation for all facts and clues bearing upon the problem
  Drawing upon past experiences, both personal and those reported in literature, for possible explanations or generalizations to account for the phenomena observed
IV. Making the best tentative explanations or hypotheses as to the possible solution of the problem
  Recognizing the assumptions which must be made if one goes beyond the known facts in formulating a hypothesis
V. Selecting the most likely hypothesis
VI. Inventing and carefully planning one or more experiments to test the hypothesis, isolating the experimental factor whenever possible by using a control
  Deciding upon the kinds of evidence which should be collected
  Choosing reliable methods of collecting the evidence
  Refining measuring instruments to the degree warranted by the nature of the problem
  Practicing to gain skill in manipulation in order to secure accurate results
VII. Testing the hypothesis by carrying out the experiment with great care and accuracy
  Preventing as far as possible all uncontrolled variations in the conditions which might affect the results
  Making quantitative measurements of experimental results and estimating the probable error of such measurements
  Recording the results, adhering strictly to standard definitions and usage of scientific terms

Organizing the pertinent data so that they may be studied and summarized

VIII. Running check experiments involving the same experimental factor to verify the results secured in the original experiment

Studying the conditions of the experiment in order to detect any omission, defects, or errors, particularly those errors which might have been introduced in the experimental results by coincidence or chance

Recognizing and, if possible, checking further the validity of the assumptions involved in setting up the experiment

IX. Drawing a conclusion

Arriving at a solution to the problem based on an honest, unbiased appraisal of the data

Suspending judgment when results are not conclusive

Calling attention in the conclusion to those basic assumptions which it has been necessary to maintain throughout the procedure

X. Making inferences based on this conclusion when facing new situations in which the same factors are operating

Cunningham (1946) in a review of 52 studies covering a span of twenty-six years related to lecture demonstration versus individual laboratory method, felt confident to make these conclusions on the topic:

> (1) When ordinary written information tests are to be used in the evaluation of the results of teaching and when all other important factors in the teaching situation are, or can be made, favorable, consider the use of the lecture demonstration method if: the learning involved in connection with the exercises is complicated and difficult; the apparatus used is complicated, difficult to manipulate, or expensive; the apparatus used is sufficiently large to be seen at a distance; the pupils are likely to make mistakes, when working alone, in determining and interpreting the results after an exercise has been completed; a large amount of subject matter must be covered in a limited time.
>
> (2) When ordinary written information tests are to be used in the evaluation of the teaching results and when all other important factors in the teaching situation are, or can be made, favorable, consider the use of individual laboratory work if: the exercises are short and easy--not complicated as to learning involved or apparatus used; caring for individual differences seems especially desirable; the results can be easily seen and interpreted, by the pupils working alone, after the exercise has been performed. There are some data

which indicate that the individual laboratory method may have merit in easy laboratory exercises even though they extend over a rather long time--especially if several observations must be made over a period of days. A few data were found which indicate that girls made a little better use of the individual laboratory method than boys.

(3) Teachers should consider doing a high proportion of the laboratory exercises by the individual laboratory method if one important objective is the development of laboratory skills.

(4) Teachers should consider doing a high proportion of the laboratory work by the individual laboratory method, without specific directions, if one important objective is the development of ability to solve laboratory problems.

(5) Teachers should consider doing a high proportion of the laboratory work by the individual laboratory method when one important objective is the development of laboratory resourcefulness.

(6) The use of both methods in a science course will make for greater variety of experiences and therefore increased interest on the part of pupils.

(7) General ability in scientific thinking is so complicated--made up of so many different steps with certain safeguards necessarily surrounding each step that both methods can probably be used to advantage in its development.

The 46th National Society for the Study of Education (1947) has identified what it believes to be criteria by which to formulate objectives. These criteria are: (1) The statement should be practicable for the teacher, (2) the statement should be psychologically sound, (3) the objective should be possible of attainment under reasonably favorable circumstances and to a measurable degree, (4) the selected objective should be universal in a democratic society, (5) the statement of the objective should clearly show the relationship of classroom activity to desired changes in human behavior.

The committee then proposed the following types of objectives: (A) functional information or facts, (B) functional concepts,

(C) functional understanding of principles, (D) instrumental skills, (E) problem solving skills, (F) attitudes, (G) appreciation, and (H) interests.

The following list of objectives was offered, not as being an exhaustive list but to "indicate directions of growth."

Types of Objectives for Science Teaching

A. Functional information or facts about such matters as:
   1. Our universe--earth, sun, moon, stars, weather, and climate.
   2. Living things--plants and animals.
   3. The human body--structure, functions, and care.
   4. The nature of matter--elements, compounds, mixtures, chemical change, physical change, solids, liquids, bases.
   5. Energy--sources, types of energy, machines.
   6. Contributions of science to the life of our times--radio, telephone, telegraph, electric lights, motion picture, household appliances, and airplanes.
B. Functional concepts, such as:
   1. Space is vast.
   2. The earth is very old.
   3. All life has evolved from simpler forms.
   4. All matter is probably electrical in structure
C. Functional understanding of principles, such as:
   1. All living things reproduce their kind.
   2. Changes in the seasons and differences in weather and climate depend largely upon the relation of the earth to the sun.
   3. Energy can be changed from one form to another.
   4. All matter is composed of single elements or combinations of elements.
   5. Living things in a given environment or locality are mutually interdependent.
D. Instrumental skills, such as ability to:
   1. Read science content with understanding and satisfaction.
   2. Perform fundamental operations with reasonable accuracy.
   3. Perform simple manipulatory activities with science equipment.
   4. Read maps, graphs, charts, and tables and to interpret them.
   5. Make accurate measurements, readings, titrations, etc.
E. Problem-solving skills, such as ability to:
   1. Sense a problem.

2. Define the problem.
3. Study the situation for all facts and clues bearing upon the problem.
4. Make the best tentative explanations or hypotheses.
5. Select the most likely hypothesis.
6. Test the hypothesis by experimental or other means.
7. Accept tentatively, or reject the hypothesis and test other hypotheses.
8. Draw conclusions.

F. Attitudes, such as:
   1. Open-mindedness--willingness to consider new facts.
   2. Intellectual honesty--scientific integrity, unwillingness to compromise with truth as known.
   3. Suspended judgment--scientific control, withholding conclusions until all available facts are in, not generalizing from insufficient data.

G. Appreciations, such as:
   1. Appreciation of the contributions of scientists.
   2. Appreciation of basic cause-and-effect relationships.
   3. Sensitivity to possible uses and applications of science in personal relationships and disposition to use scientific knowledge and abilities in such relationships (attitude).

H. Interests, such as:
   1. Interest in some phase of science as a recreational activity or hobby.
   2. Interest in science as a field for a vocation.

The committee comments on the "problem solving skills" of the above list:

> The problem solving skills are those employed in reflective thinking. . . . Although most science teachers profess great faith in problem solving skills as objectives of science instruction, no objectives are probably more vaguely thought of or less specifically made the purpose of instruction. . . . The position of the committee as it relates to the object . . . stated clearly and positively:
>
> a) It is possible to train pupils in scientific techniques of problem solving. That improvement in such skills is attainable through science instruction.
>
> b) The success of such training is increased as the objectives are specifically defined and as they are definitely made purposes in instruction. This means that again, as in the case of transfer of training, gains are increased when the teacher tells the learner what the goals of instruction are, or, perhaps better still, they agree on them together. It is the teacher's responsibility to make certain that the learner identifies the objectives and that opportunity for, and practice in, generalizing or transfer is provided.

> c) Problem-solving skills should be developed wherever and whenever the situation seems appropriate. Many ordinary situations in the laboratory and classroom can be utilized by the alert teacher for experience in developing these skills. There can, of course, be separate units to deal with them, but attention to these objectives should not be confined to such units.

Regarding "Attitudes", "Appreciations", and "Interests", the committee takes the position that these objectives are:

> . . . in all probability, no less tangible than are other types of objectives. Moreover, once we accept them as objectives and once we really look for them, they reveal themselves no less clearly in behavior. . . . The task of engendering desirable science attitudes, interests, and appreciations is twofold. It consists in part in building a sound foundation in accurate information, concepts, and principles. And it consists in part in emotionalizing this knowledge content to the point that it will carry over into action.

McGrath (1948), in summarizing the material contributed by twenty-one leading colleges and universities, lists four possible objectives for non-science major students who take general education college science courses. These are:

1. To understand and learn to use the method of science
2. To become acquainted with some of the more important facts of science
3. To become aware of the social implications of science
4. To appreciate the historical development of science.

Nedelsky (1949) makes the most specific statement so far regarding the responsibility of the American colleges as relates to objectives as he says:

> The writer maintains . . . that the first step toward the badly needed revision of American college education is for the colleges to state clearly the desired outcomes of higher education . . . the objectives of a course of study or of a curriculum of a college should be stated explicitly and in considerable detail; that teaching should be directed consciously and specifically toward the achievement of these objectives, and that the degree of achievement of the objectives should be measured.

Nedelsky then offers the following list of behavior objectives:

1. Knowledge

This objective has been variously described as: possession of information; grasp of the subject matter; acquaintance with the main facts; knowledge of the course; textbook knowledge; remembering what was taught in the course. The last is very nearly the sense in which the word knowledge is here used to designate this objective. The main ability to be tested for in the exercises under this heading, or at least the ability that can most reliably be tested, is memory. Success in the test will probably depend, however, on other abilities, notably on the ability to organize and relate the materials studied; this ability in turn depends on the student's intelligence. It must be emphasized, however, that the ability to organize is not to be tested for directly; the ability to organize is to be of help to the student primarily as a mnemonic device. The three main subheads 1.1, 1.2, and 1.3 are arranged in the order of increasing demand in this ability.

1.1 Subject matter knowledge (straight memory questions).

1.11 Knowledge of laws and principles (verbal and mathematical.

1.12 Knowledge of theories.

1.13 Knowledge of facts (e.g., density of iron).

1.14 Knowledge of technical terms, symbols, units, dimensions, etc.

1.2 Analytical knowledge. This is the knowledge of the relations or patterns studied in the course; it is thus of a more functional nature than subject matter knowledge (1.1). The ability to organize the materials of the course should be of help to most students in retaining these relations. It is important to notice, however, that these relations or patterns are to be tested for in nearly the same context in which they appeared in the course; if the context or the situation were genuinely novel, not the memory of the relation, but the ability to discern it, would be tested. Such an ability in the writer's scheme of classification does not belong under the heading of knowledge.

1.21 Knowledge of the relation between empirical generalizations (laws of nature) and specific phenomena. (The generalizations are those taught in the course.)

1.22 Knowledge of the bases of theories; of relation between theories and facts. (The theories, assumptions, evidence, etc. are those taught in the course.)

1.23 Knowledge of experimental procedures: instruments, factors affecting the validity of the experiment; etc. (All of these having been taught in the course.)

1.24 Knowledge of the appropriate sources of information (whether to consult a textbook, a journal, etc.)

1.3 Knowledge of methodology. Here the student is to be tested for the knowledge of the structures of the separate physical sciences, the relation of these sciences to one another, and their relation to other fields. As in Sec. 1.2, only those structures and relations which were specifically taught in the course belong in this category.

1.31 Knowledge of the nature and structure of the physical sciences (or physics).

1.32 Knowledge of the historical development of the science.

1.33 Knowledge of the realm of the physical science (or physics) and of its branches.

2. Ability to Use the Methods of Science

Other phrases used to describe this ability are: working knowledge of science; critical thinking in science; mastery of the scientific method; possession of the tools of science; ability to act as a scientist; possession of mental or intellectual skills used by scientists. While in Secs. 1.1 to 1.3 the student is to be asked essentially to reproduce what he heard or read in the course, in this section it is desired to know what the student can do when more or less on his own. It is therefore necessary that the situations used contain elements that are new to the student. At the same time it is necessary, in general, that the situations be of the same kind as those studied in the course; otherwise, it is unlikely that the ability of the student to handle the situation could have been improved by the course. Thus it does not seem fair to ask a student whether a given experiment could be used as evidence for a given theory unless the course had presented some experimental evidence for some theory so that the student knows the general pattern expected. At the other extreme, if that particular experiment was quoted in the course as evidence for that particular theory, the item properly belongs in Sec. 1.2.

2.1 Ability to use methods of science in abstract situations. The exercises are to test the student's ability to use methods of science in situations that are well defined and clear cut and in which a minimum of content knowledge in the sense of Sec. 1.1 is required.

2.11 Ability to apply stated principles. (A principle is stated: the student is to apply it to a situation described.)

2.12 Ability to carry out symbolically indicated operations.

2.13 Ability to use syllogisms.

2.2 Ability to use methods of science in 'academic' situations. These are situations which are new to the student; their complexity, however, is about the same as that of the situations used in the course for illustrative purposes. Usually a single principle, law, or theory is sufficient for the analysis of the situation.

2.21 Ability to relate empirical generalization (laws of nature) and specific phenomena. (Although the student may be familiar both with the generalization and the specific phenomenon, the particular relation between these that is used in the test question must be one that was not taught in the course.)

2.22 Ability to relate theories and facts. (The relation between the theory and the facts of the test question must be new to the student.)

2.23 Ability to analyze and criticize an experiment. (The experiment described must be new to the student.)

2.3 Ability to use methods of science in 'whole' situations. These are situations approximating those the student may face in real life--outside the classroom. They are characterized by greater complexity than the 'academic' situations of Sec. 2.2. Exercises included in this section are to be limited to those situations which have not been taught in the course and which require more than one principle--or even more than one branch of science--for their analysis.

2.31 Ability to use methods of physics.

2.32 Ability to use methods of the physical sciences.

2.33 Science and society. (Situations made complex by the mores, etc., of the community.)

3. Ability to Read Scientific Literature

Here the ability to read is used in its widest possible sense; it ranges from understanding the literal meaning of particular sentences or the information conveyed by graphs, drawings, and tables to inferring the conceptual framework used by the author.

3.1 Ability to read a book or a long article. The book may have been read and discussed in the course or assigned for reading before the student came to the examination. The particular questions that appear in the test, however, should not have been discussed in class.

3.2 Ability to read a passage. The passage to be read and the questions asked should be so chosen that the student would not be able to answer the questions without a thorough understanding of the passage. Ordinarily the passage must be on a topic not taught in the course.

3.3 Ability to interpret tables, graphs, drawings, etc. Tables, graphs, and questions should be so chosen that the student would not be able to arrive at correct answers merely from his previous knowledge of the physical principles involved.

3.31 Ability to interpret a table of values.
3.32 Ability to interpret graphical data.

4. Proper Attitudes and Habits

It is possible to learn something about the student's attitude and habits of thought by analyzing the kind of wrong answers that he seems to prefer. The attitudes and habits listed below form no more than a sample.

4.1 Attitude of overcautiousness vs. that of jumping to conclusions or going beyond data.

4.2 Attitude of underestimating the power and value of science vs. that of overestimating these or depending on the methods of empirical science in the fields of philosophy, religion, etc.

4.3 Attitude of underestimating the value of experiment or observation as tools of science vs. that of underestimating the importance of reason or of the man-made nature of science.

4.4 Possession of strong prejudices or preconceptions.

4.5 The habit of learning things well, or not at all vs. that of learning something of everything.

Nedelsky then identifies the criteria which he feels should be used in making up the list of behavior objectives as: (1) Communicability, at the level of teaching and testing, such that the teachers will be able to make up their own test-exercises that test for the objective; (2) Importance, there should be common agreement among professional members of the field; (3) Teachability, they must be realizable; (4) Testability, in that it is necessary to write the objective in terms of the students' behavior and to choose a test situation in which this behavior could be exhibited; (5) Comprehensiveness, the list of objectives should include all the important, desirable and realizable outcomes of instruction.

Burmester (1952) provides a comprehensive list of behaviors involved in the critical aspects of scientific thinking. Her list is based upon the earlier work of Keeslar (1945), Burke (1949), Hawkes, Lindquist, and Mann (1936), Smith and Tyler (1942), Johnson (1943), "Science in General Education" (1938), The Committee on Research in Secondary School Science (1949), and Flanagan (1949).

1.00 Ability to recognize problems.
- 1.10 Ability to recognize a problem or a perplexity in the context of a paragraph or an article.
- 1.20 Ability to distinguish between a fact (observation) and a perplexity or problem.
- 1.30 Ability to recognize a problem even when it is stated in expository form rather than in interrogatory form.
- 1.40 Ability to distinguish a problem from a possible solution to a problem (hypothesis) even when the hypothesis is presented in interrogatory form.
- 1.50 Ability to avoid becoming diverted from the major problem into side issues.

2.00 Ability to delimit a problem.
- 2.10 Ability to distinguish between major and minor problems.
- 2.20 Ability to isolate the single major problem or single major idea in a problem.
- 2.30 Ability to see the relationship of minor problems to the major problems.
- 2.40 Ability to distinguish between relevant and irrelevant problems.
- 2.50 Ability to analyze the problem into its essential parts.
- 2.60 Ability to concentrate on the main problem.
- 2.70 Ability to recognize the basic assumptions of a problem.

3.00 Ability to recognize and accumulate facts related to the solution of a problem.
- 3.10 Ability to select the kind of information needed to solve the problem.
- 3.20 Ability to recognize valid evidence.
- 3.30 Ability to differentiate between reliable and unreliable sources of information.
- 3.40 Ability to select data pertinent to the solution of the problem.
- 3.50 Ability to recognize the difference between data pertinent to the solution of the problem and that which is unrelated.

4.00 Ability to recognize an hypothesis.
- 4.10 Ability to distinguish an hypothesis from a problem.
- 4.20 Ability to differentiate between a statement that describes an observation and a statement which is an hypothesis about the fact.
- 4.30 Ability to distinguish between an hypothesis as a possible solution to a problem and a conclusion (probable solution to a problem).
- 4.40 Ability to recognize the tentativeness of an hypothesis.

5.00 Ability to plan experiments to test hypothesis.
- 5.10 Ability to select the most reasonable hypothesis to test.
- 5.20 Ability to differentiate between an uncontrolled observation and an experiment involving controls.
- 5.30 Ability to recognize the fact that only one factor in an experiment should be variable.
  - 5.31 Ability to recognize what factors must be controlled.
  - 5.32 Ability to recognize the overall control.
  - 5.33 Ability to recognize the partial controls.
  - 5.34 Ability to recognize the variable factor.
  - 5.35 Ability to understand why the overall control was included in an experiment.
  - 5.36 Ability to recognize the factor being held constant in the overall control.
  - 5.37 Ability to recognize the factors being held constant in the partial controls.
- 5.40 Ability to recognize experimental and technical problems inherent in the experiment.
- 5.50 Ability to criticize faulty experiments when:
  - 5.51 The experimental design was such that it could not yield an answer to the problem.
  - 5.52 The experiment was not designed to test the specific hypothesis stated.
  - 5.53 The method of collecting the data was unreliable.
  - 5.54 The data were not accurate.
  - 5.55 The data were insufficient in number.
  - 5.56 Proper controls were not included.
  - 5.57 No controls were included.

6.00 Ability to carry out experiments.
- 6.10 Ability to recognize existence of errors in measurement.
- 6.20 Ability to recognize when the precision of measurement given is warranted by the nature of the problem.
- 6.30 Ability to make accurate observations.
  - 6.31 Ability to observe differences in situations which are similar.
  - 6.32 Ability to observe similarities in situations which are different.

6.40 Ability to organize facts into tables, graphs, etc. for easy interpretation.

7.00 Ability to interpret data.
- 7.10 Ability to handle certain basic skills necessary to the interpretation of data.
  - 7.11 Ability to read tables and graphs.
  - 7.12 Ability to perform simple computations.
- 7.20 Ability to evaluate relevancy of data.
  - 7.21 Ability to recognize hypothesis and conclusions contradicted by the data.
  - 7.22 Ability to recognize hypotheses and conclusions which are unrelated to the data.
  - 7.23 Ability to select the hypothesis from a group of hypotheses which most adequately explains the data.
  - 7.24 Ability to recognize facts which support an hypothesis or a conclusion.
  - 7.25 Ability to recognize facts which contradict an hypothesis or a conclusion.
- 7.30 Ability to differentiate between facts and inferences.
  - 7.31 Ability to differentiate between an observation and a conclusion drawn from the observation.
  - 7.32 Ability to differentiate a conclusion from an hypothesis.
  - 7.33 Ability to distinguish an assumption upon which a conclusion depends and the conclusion itself.
  - 7.34 Ability to distinguish a fact from an assumption.
- 7.40 Ability to recognize the limitations of data.
  - 7.41 Ability to differentiate between what is established by the data alone and what is implied by the data.
  - 7.42 Ability to recognize that a statement which goes beyond the data cannot be absolutely true.
  - 7.43 Ability to recognize that generalizations from results of an experiment can only be extended to new situations when there is considerable similarity between the situations.
  - 7.44 Ability to confine definite conclusions to the evidence at hand.
- 7.50 Ability to consider as possibly true or probably true inferences based on the data.
  - 7.51 Ability to make inference on the basis of trends.
  - 7.52 Ability to extrapolate.
  - 7.53 Ability to interpolate.
  - 7.54 Ability not to be so overcautious that all statements which go beyond the data are rejected because of insufficient evidence.
- 7.60 Ability to perceive relationships in data.
  - 7.61 Ability to make comparisons.
  - 7.62 Ability to see element in common to several items of data.

7.63 Ability to recognize prevailing tendencies and trends in data.
7.64 Ability to recognize that when two things vary together that there may be a relationship between them, but does not assign cause and effect judgments on ths basis of this relationship.
7.65 Ability to formulate reasonable generalizations based upon the data.

7.70 Ability to recognize the nature of evidence.
7.71 Ability to recognize the difference between direct and indirect evidence.
7.72 Ability to recognize a statement which is given as evidence as not being evidence when the statement contradicts the conclusion.
7.73 Ability to recognize a statement which is given as evidence as not being evidence when the statement is unrelated to the conclusion.
7.74 Ability to recognize evidence for an inference and to choose such evidence from a series of statements.
7.75 Ability to recognize the validity of the evidence used to support conclusions.

7.80 Ability to recognize the assumptions involved in the formulation of hypotheses and conclusions.
7.81 Ability to recognize assumptions which go beyond the data but which are essential to the formulation.
7.82 Ability to recognize assumptions which must be maintained in the drawing of a conclusion.
7.83 Ability to recognize assumptions which can be checked experimentally.
7.84 Ability to recognize invalid assumptions.

8.00 Ability to apply generalizations to new situations.
8.10 Ability to refrain from applying generalizations to new situations does not closely parallel the experimental situation.
8.20 Ability to be aware of the tentativeness of predictions about new situations even when there is a close parallel between the two situations.
8.30 Ability to recognize the assumptions which must be made in applying a generalization to a new situation.

Obourn (1956) states:

Very little reliable evidence is available to indicate the extent to which the problem solving objective is provided for in day-to-day classroom activities. Still less evidence is available on the extent to which the objective is achieved with the young people who study science.

> Among other difficulties in reaching the fullest attainment of the objective is the failure, on the part of many teachers, to recognize that problem solving behavior is a complex ability made up of elements which can be identified.

and then presents the following analysis of the attitudes of mind that accompany problem solving behavior:

I. Attitudes which can be developed through science teaching
The science program should develop the attitude which will modify the individual's behavior so that he:

A. Looks for the natural cause of things that happen
   1. Does not believe in superstitutions such as charms or signs of good or bad luck
   2. Believes that there is necessarily no connection between two events just because they occur at the same time

B. Is openminded toward work, opinions of others, and information related to his problem
   1. Believes that truth never changes, but that his ideas of what is true may change as he gains better understanding of the truth
   2. Bases his ideas upon the best evidence and not upon tradition alone
   3. Revises his opinions and conclusions in light of additional reliable information
   4. Listens to, observes, or reads evidence supporting ideas contrary to his personal opinions
   5. Accepts no conclusion as final or ultimate

C. Bases opinions and conclusions on adequate evidence
   1. Is slow to accept as facts any that are not supported by convincing proof
   2. Bases his conclusions upon evidence obtained from a variety of dependable sources
   3. Hunts for the most satisfactory explanation of observed phenomena that the evidence permits
   4. Sticks to the facts and refrains from exaggeration
   5. Does not permit his personal pride, bias, prejudice or ambition to pervert the truth
   6. Does not make snap judgments or jump to conclusions

D. Evaluates techniques and procedures used, and information obtained
   1. Uses a planned procedure in solving his problems
   2. Uses the various techniques and procedures which may be applied in obtaining information

3. Adapts the various techniques and procedures to the problems at hand
4. Personally considers the information obtained and decides whether it relates to the problem
5. Judges whether the information is sound, sensible, and complete enough to allow a conclusion to be made
6. Selects the most recent, authoritative, and accurate information related to the problem

E. Is curious concerning the things he observes
1. Wants to know the "whys," "whats" and "hows" of observed phenomena
2. Is not satisfied with vague answers to his questions

II. Problem solving abilities which can be developed through science teaching

The science program should develop those abilities involved in problem solving which will modify the individual's behavior so that he:

A. Formulates significant problems
1. Senses situations involving personal and social problems
2. Recognizes specific problems in these situations
3. Isolates the single major idea in the problem
4. States the problem in question form
5. States the problem in definite and concise language

B. Analyzes problems
1. Picks out the key words of a problem statement
2. Defines key words as a means of getting a better understanding of the problem

C. Obtains information regarding a problem from a variety of sources
1. Recalls past experiences which bear upon his problem
2. Isolates elements common in experience and problem
3. Locates source materials
   a. Uses the various parts of a book
      (1) Uses key words in the problem statement for locating material in the index
      (2) Chooses proper sub-topics in the index
      (3) Uses alphabetized materials, cross references, the table of contents, the title page, the glossary, figures, pictures and diagrams, footnotes, topical headings, running headings, marginal headings, an appendix, a pronunciation list, and 'see also' references

b. Uses materials other than textbooks such as: encyclopedias, popularly written books, handbooks, dictionaries, magazines, newspapers, pamphlets, catalogues, bulletins, films, apparatus, guide letters, numbers, signs, marks in locating information, bibliographies
c. Uses library facilities such as: the card index, The Reader's Guide, and the services of the libraries.

4. Uses source materials
   a. Uses aids in comprehending material read
      (1) Finds main ideas in a paragraph
      (2) Uses reading signals
      (3) Formulates statements from reading
      (4) Phrases topics from sentences
      (5) Skims for main ideas
      (6) Learns meanings of words and phrases from context
      (7) Selects the printed material related to the problem
      (8) Cross-checks a book concerning the same topic
      (9) Recognizes both objective and opinionated evidence
      (10) Determines the main topic over several paragraphs
      (11) Takes notes
      (12) Arranges ideas in an organized manner
      (13) Makes outlines
   b. Interprets graphic material
      (1) Obtains information from different kinds of graphic material
      (2) Reads titles, column headings, legends and data recorded
      (3) Evaluates conclusions based upon the data recorded
      (4) Formulates the main ideas presented
5. Uses experimental procedures appropriate to the problem
   a. Devises experiments suitable to the solution of the problem
      (1) Selects the main factor in the experiment
      (2) Allows only one variable
      (3) Sets up a control for the experimental factor
   b. Carries out the details of the experiment
      (1) Identifies effects and determines causes
      (2) Tests the effects of the experimental factor under varying conditions
      (3) Performs the experiment for a sufficient length of time
      (4) Accurately determines and records quantitative and qualitative data

(5) Develops a logical organization of recorded data
(6) Generalizes upon the basis of organized data

c. Manipulates the laboratory equipment needed in solving the problem
(1) Selects kinds of equipment or materials that will aid in solving the problem
(2) Manipulates equipment or material with an understanding of its function to the outcome of the experiment
(3) Recognizes that equipment is only a means to the end result
(4) Determines the relationship between observed actions or occurrences and the problem
(5) Appraises scales and divisions of scales on measuring devices
(6) Obtains correct values from measuring devices
(7) Recognizes capacities or limitations of equipment
(8) Returns equipment clean and in good condition
(9) Avoids hazards and consequent personal accidents
(10) Practices neatness and orderliness
(11) Avoids waste in the use of materials
(12) Exercises reasonable care of fragile or perishable equipment

6. Solves mathematical problems necessary in obtaining pertinent data
a. Picks out the elements in a mathematical problem that can be used in its solution
b. Sees relationships between these elements
c. Uses essential formulae
d. Performs fundamental operations as addition, subtraction, multiplication and division
e. Uses the metric and English system of measurement
f. Understands the mathematical terms used in these problems; i.e. square, proportion, area, volume, etc.

7. Makes observation suitable for solving the problem
a. Observes demonstrations
(1) Devises suitable demonstrations
(2) Selects materials and equipment needed in the demonstration
(3) Identifies the important ideas demonstrated
b. Picks out the important ideas presented by pictures, slides, and motion pictures

c. Picks out the important ideas presented by models and exhibits
d. Uses the resources of the community for purposes of obtaining information pertinent to the problem
   (1) Locates conditions or situations in the community to observe
   (2) Picks out the essential ideas from such observation

8. Uses talks and interviews as sources of information
   a. Selects individuals who can contribute to the solution of the problem
   b. Makes suitable plans for the talk or interview
   c. Appropriately contacts the person who is to talk
   d. Selects the main ideas from the activity
   e. Properly acknowledges the courtesy of the individual interviewed

D. Organizes the data obtained
   1. Uses appropriate means for organizing data
      a. Constructs tables
      b. Constructs graphs
      c. Prepares summaries
      d. Makes outlines
      e. Constructs diagrams
      f. Uses photographs
      g. Uses suitable statistical procedures

E. Interprets organized data
   1. Selects the important ideas related to the problem
   2. Identifies the different relationships which may exist between the important ideas
   3. States these relationships as generalizations which may serve as hypotheses

F. Tests the hypotheses
   1. Checks proposed conclusion with authority
   2. Devises experimental procedures suitable for testing the hypotheses
   3. Rechecks data for errors in interpretation
   4. Applies hypothesis to the problem to determine its adequacy

G. Formulates a conclusion
   1. Accepts the most tenable of the tested hypotheses
   2. Uses this hypothesis as a basis for generalizing in terms of similar problem situations

Obourn then presents a checklist so that the teacher may be able to judge whether or not the classroom operation provides the conditions for fostering problem solving types of learning:

A. Sensing and Defining Problems:

To what extent do you:

1. help pupils sense situations involving personal and social problems?
2. help pupils in isolating the single major idea of a paragraph?
3. help pupils in isolating the single major idea of a problem?
4. help pupils state problems as definite and concise questions?
5. help pupils pick out and define the key words as a means of getting a better understanding of the problem?
6. help pupils evaluate problems in terms of personal and social needs?
7. help pupils to be aware of the exact meaning of word-groups and shades of meaning of words in problems involving the expression of ideas?
8. present overview lessons to raise significant problems?
9. permit pupils to discuss possible problems for study?
10. encourage personal interviews about problems of individual interest?

B. Collecting Evidence on Problems:

To what extent do you:

1. provide a wide variety of sources of information?
2. help pupils develop skill in using reference sources?
3. help pupils develop skill in note taking?
4. help pupils develop skill in using reading aids in books?
5. help pupils evaluate information pertinent to the problem?
6. provide laboratory demonstrations for collecting evidence on a problem?
7. provide controlled experiments for collecting evidence on a problem?
8. help pupils develop skill in interviewing to secure evidence on a problem?
9. provide for using the resources of the community in securing evidence on a problem?
10. provide for using visual aids in securing evidence on a problem?
11. evaluate the pupils' ability for collecting evidence on a problem as carefully as you evaluate their knowledge of facts?

C. Organizing Evidence on Problems:

To what extent do you:
1. help pupils develop skill in arranging data?
2. help pupils develop skill in making graphs of data?
3. help pupils make use of deductive reasoning in areas best suited?
4. provide opportunity for pupils to make summaries of data?
5. help pupils distinguish relevant from irrelevant data?
6. provide opportunity for pupils to make outlines of data?
7. evaluate the pupils' ability to organize evidence on a problem as carefully as you evaluate their knowledge of facts?

D. Interpreting Evidence on Problems:

To what extent do you:
1. help pupils select the important ideas related to the problem?
2. help pupils identify the different relationships which may exist between the important ideas?
3. help pupils see the consistencies and weaknesses in data?
4. help pupils state relationships as generalizations which may serve as hypotheses?
5. evaluate the pupils' ability for interpreting evidence as carefully as you evaluate their knowledge of facts?

E. Selecting and Testing Hypotheses:

To what extent do you:
1. help pupils judge the significance or pertinency of data for the immediate problem?
2. help pupils check hypotheses with recognized authorities?
3. help pupils make inferences from facts and observations?
4. help pupils devise controlled experiments suitable for testing hypotheses?
5. help pupils recognize and formulate assumptions basic to a given hypothesis?
6. help pupils recheck data for possible errors in interpretation?
7. evaluate the pupils' ability for selecting and testing hypotheses as carefully as you evaluate their knowledge of facts?

F. Formulating Conclusions:

To what extent do you:
1. help pupils formulate conclusions on the basis of tested evidence?
2. help pupils evaluate their conclusions in the light of the assumptions they set up for the problem?
3. help pupils apply their conclusions to new situations?
4. evaluate the pupils' ability to formulate conclusions as carefully as you evaluate their knowledge of facts?

Schmidt (1957) states:

> The widest consensus of opinion in recent years came from the Commission on Higher Education appointed by President Truman in 1947, composed of representative figures in higher education from all parts of the country who were asked to formulate long term objectives.

Because the President's Commission Report does attempt to pull together the ideas of the earlier reports and because it seems to choose the best thoughts of both Dewey and Hutchins, the major purposes and the recommendations are presented.

> The crucial task of higher education today, therefore, is to provide a unified general education for American youth. Colleges must find the right relationship between specialized training on the one hand, aiming at a thousand different careers, and the transmission of a common cultural heritage toward a common citizenship on the other. . . .
>
> 'General education' is the term that has come to be accepted for those phases of nonspecialized and nonvocational learning which should be the common experience of all educated men and women.
>
> General education should give to the student the values, attitudes, knowledge, and skills that will equip him to live rightly and well in a free society. It should enable him to identify, interpret, select, and build into his own life those components of his cultural heritage that contribute richly to understanding and appreciation of the world in which he lives. It should therefore embrace ethical values, scientific generalizations, and aesthetic conceptions, as well as an understanding of the purposes and character of the political, economic, and social institutions that men have devised.
>
> But the knowledge and understanding which general education aims to secure whether drawn from the past or from a living present, are not to be regarded as ends in themselves. They are means to a more abundant personal life and a stronger, freer social order.
>
> Thus conceived, general education is not sharply distinguished from liberal education; the two differ mainly in degree, not in kind. General education undertakes to redefine liberal education in terms of life's problems as men face them, to give it human orientation and social direction, to invest it with content that is directly relevant to the demands of contemporary society. General education is

liberal education with its matter and method shifted from its original aristocratic intent to the service of democracy. General education seeks to extend to all men the benefits of an education that liberates. . . .

The purposes of general education should be understood in terms of performance, of behavior, not in terms of mastering particular bodies of knowledge. It is the task of general education to provide the kinds of learning and experience that will enable the student to attain certain basic outcomes, among them the following:

1. To develop for the regulation of one's personal and civic life a code of behavior based on ethical principles consistent with democratic ideals.
2. To participate actively as an informed and responsible citizen in solving the social, economic, and political problems of one's community, state, and nation.
3. To recognize the interdependence of the different peoples of the world and one's personal responsibility for fostering international understanding and peace.
4. To understand the common phenomena in one's physical environment, to apply habits of scientific thought to both personal and civic problems, and to appreciate the implications of scientific discoveries for human welfare.

   The scientific account of the natural world must, of course, hold a prominent place in the school experience of all educated persons. To simplify the account and give it relevance for the life and problems of ordinary men is one of the most important and at the same time most difficult objectives of general education. What is needed . . . is the integration of the significant methods and findings of the natural sciences into a comprehensive synthesis that will bring to the general student understanding of the fundamental nature of the physical world in which he lives and of the skills by which nature is discovered.

   That the student group the processes involved in scientific thought and understand the principles of scientific method is even more important than that he should know the data of the sciences. The spirit of science--including intellectual curiosity, openness of mind, passion for truth wherever it may lead, respect for evidence, and the free communication of discoveries--should be the product of education at all levels.

   General education in science must also emphasize the social significance of science and technology of our times. Failure to understand how science has transformed the conditions under which men live is failure to understand the forces that have reshaped our civilization and now threaten to destroy it.

5. To understand the ideas of others and to express one's own effectively.
6. To attain a satisfactory emotional and social adjustment.
7. To maintain and improve his own health and to cooperate actively and intelligently in solving community health problems.
8. To understand and enjoy literature, and music, and other cultural activities as expressions of personal and social experience, and to participate to some extent in some form of creative activity.
9. To acquire the knowledges and attitudes basic to a satisfying family life.
10. To choose a socially useful and personally satisfying vocation that will permit one to use to the full his particular interests and abilities.
11. To acquire and use the skills and habits involved in critical and constructive thinking.

Ability to think and to reason, within the limits set by one's mental capacity, should be the distinguishing mark of an educated person. Development of the reasoning faculty, of the habit of critical appraisal, should be the constant and pervasive aim of all education, in every field and at every level. . . .

More to the purpose and of much more lasting effect would be emphasis on the student's acquiring familiarity with the process of inquiry and discovery. Insofar as education is not indoctrination it is discovery, and discovery is the product of inquiry. Arousing and stimulating intellectual curiosity, channeling this curiosity into active and comprehensive investigation, and developing skill in gathering, analyzing, and evaluating evidence--these should constitute the primary job of every teacher from the elementary grades through the university. The open and inquiring mind and the habit of rigorous and disciplined investigation are the marks of freemen and the sinew of a free society.

General education, therefore, will concentrate, not on the mastery of specific information, but on the fullest possible development of the motives, attitudes, and habits that will enable the student to inform himself and think for himself throughout life. It will stress (1) the importance of being informed, of basing decisions, actions, and opinions on accurate facts; (2) knowledge of where and how to acquire information; and (3) ability to appraise, relate, and integrate facts in order to

> form valid judgments. The habit of making this approach to any situation can best be developed by leading the student to apply it at every opportunity in his life on the campus, in solving problems both inside and outside the classroom.

Watson (1963) reviewed the work of Kruglak (1951, 1952, 1953, 1954, 1955a and 1958), Kruglak and Goodwin (1955), Lahti (1956), Brown (1958), and Frings and Hichar (1958), all of which considered the functions of the laboratory in science.

A summary of the conclusions from these studies was: (1) individual laboratory work does not lead to greater resourcefulness in (a) solving new problems, (b) designing experiments, (c) interpreting results of experiments, (d) utilizing facts and principles; (2) paper and pencil laboratory tests designed to evaluate specific laboratory outcomes have few elements in common with laboratory performance tests consisting of more comprehensive tasks, (3) performance tests measure instructional outcomes other than those measured by conventional achievement tests, and (4) the presence or absence of high school laboratory work was not a significant predictor on the final examination of college physics.

Van Deventer (1960), regarding science for general education, states:

> There is no definable trend in the use of laboratory or demonstration in the teaching of these courses. The methods spectrum may range from a course based on readings, in which the only method used is discussion, through courses employing discussion plus occasional lectures and demonstrations, to the far end of the continuum where the laboratory method, including open-end experiments, is a prominent feature. If a trend does exist, it is toward the adoption of a multiple method including lecture, discussion, and demonstration, with individual and group laboratory.

Chrenois (1962) sets down what he feels to be the aims of his introductory general education chemistry course when he states:

> . . . everyone will agree that the aim of science education is to obtain expert knowledge in one of the areas of science. . . .
>
> The chief objective of any introductory course in chemistry is to study the materials of our world, their nature, properties, structure and transformations in such a manner as to contribute to the student's general education as a citizen. More specifically such a study will try to attain the following:
>
> To give an understanding of the historical development of chemistry, its relation to other fields of science, its significance in the modern complex technological society, and its potentialities for good or evil;
>
> To develop an understanding of the methods of science and to help the student, through the use of such methods, to acquire an unbiased critical attitude;
>
> To develop through intensive study an understanding of the nature of matter and its transformation, particularly the living processes and those used by man to overcome the limitations imposed by his natural environment.
>
> It will be obvious that the first two specific objectives need no laboratory instruction. Both can be developed and taught by any expository method. However, the third objective is the heart of any introductory course in chemistry and the first two can only be realized by organization of the subject matter selected for the attinment of the third.
>
> The heart of any introductory course in chemistry, therefore, is the study of the nature of matter, its transformations, and the energy relationships involved in these transformations. The problem is to discover how demonstrations of experiments or individual laboratory practice, or both, aid in the attainment of such an objective.

Cheronis also provided the following as aims of laboratory instruction:

> The aims of laboratory instruction are:
>
> To have the students learn the rudiments of manipulation and techniques so that they can work safely in performing simple experiments with the minimum amount of supervision;
>
> To have them learn first hand a few facts about the physical and chemical properties of selected chemical elements and compounds, so as to obtain an elementary chemical orientation;

To teach the students to provide illustrations of a few selected chemical concepts and principles by themselves, so that with the aid of the instructor they can relate these concepts and principles to the theories that explain them;

To enable the students to apply the facts and principles which have been learned to a novel situation or problem, such as is presented by the so-called solution of an unknown.

McKeachie (1963) states:

The laboratory method is now so widely accepted in scientific education that it may seem heretical to ask whether laboratory experience is an effective way to achieve educational objectives.

Laboratory teaching assumes that first-hand experience in observation and manipulation of the materials of science is superior to other methods of developing understanding and appreciation.

From the standpoint of theory, the activity of the student, the sensorimotor nature of the experience, and the individualization of laboratory instruction should contribute positively to learning. Information cannot usually be obtained, however, by direct experience as rapidly as it can from abstractions presented orally or in print. Films or demonstrations may also short-cut some of the trial and error of the laboratory. Thus, one would not expect laboratory teaching to have an advantage over other teaching methods in amount of information learned. Rather we might expect the differences to be revealed in retention, in ability to apply learning, or in actual skill in observation or manipulation of materials. Unfortunately, little research has attempted to tease out these special types of outcomes. If these outcomes are unmeasured, a finding of no difference in effectiveness between laboratory and other methods of instruction is almost meaningless since there is little reason to expect laboratory teaching to be effective in simple communication of information.

Actually all of these studies point to the importance of developing understanding rather than teaching students to solve problems by going through a routine series of steps. Whether or not laboratory is superior to lecture-demonstration in developing understanding and problem-solving skills probably depends upon the extent to which understanding of concepts and general problem-solving procedures are emphasized by the instructor in the laboratory situation.

Jeffries (1967) provides the following as the major objectives of chemistry laboratory instruction:

1. Communicative Competence: A knowledge of terminology involving the ready recall of the names of items of equipment, of general operations, and of special operations when confronted with them in some non-verbal way.

2. Observational Competence: Ability to see what is going on in the immediate laboratory area, to distinguish good practice from bad, to recognize the occurrence of change in condition, to recognize differences such as the odd one of a number of apparently similar objects or the like pair in a group of apparently dissimilar objects.

3. Investigative Competence: Knowledge of the use of the tools of the laboratory, ability to design experiments to quantify characteristics, ability to design experiments to identify or separate substances, ability to order data, ability to formulate a hypothesis, ability to design an experiment to test a hypothesis, ability to predict effects of actions, ability to search the literature, ability to use standard chemical handbooks.

4. Reporting Competence: Ability to maintain a legally sufficient record of a laboratory experiment and ability to report the results in clear, concise language.

5. Manipulative Competence: Ability to handle laboratory equipment and supplies in a skillful manner; i.e., with safety to experiment, persons, and equipment, in a rapid manner; and in an accurate manner.

6. Laboratory Discipline: The self discipline to observe safe practices, to maintain an orderly laboratory, especially when equipment and/or supplies are used in common, and to be exact in the reporting of data regardless of the consequences.

Ramsey and Howe (1969) comment:

> It has become almost self-evident that one of the aims of science teaching is to develop problem-solving skills and that the laboratory is the place where the student may be introduced to the experimental method for solving problems. Yet very few studies in the literature describe attempts to analyze the processes of problem-solving by high school students.
>
> . . . It has been suggested, and indeed it is the trend in many of the course improvement projects, to make laboratory experiences central to instructional procedures in science. Yet direct research on what these experiences should be, how they should be organized, and where they function best, is indeed meager.

> There is evidence to suggest that it is worth increasing the number of 'open-ended' experiments used in class. Laboratory experiences should be designed as problem-solving experiences, and should be directed to specified learning outcomes. More research is needed on how students solve problems both individually and in groups so that more efficient instructional procedures can be designed.

An analysis of various reports on experiences in science instruction in general education since the pioneering work of Colton (1925) leads to the following generalizations:

(1) A knowledge of specific facts, laws, and principles of science is considered less important as an outcome of science instruction for purposes of general education than that for professional or preprofessional purposes.

(2) Statements of objectives and statements about objectives of science for purposes of general education are much more common in discussions and descriptions of science courses for general education than in courses for scientific professional or preprofessional education.

(3) "Scientific method" stated and expressed in many different ways is almost always included as one of the major objectives of science courses for purposes of general education.

(4) There is little agreement concerning the major topics or content to be dealt with in science courses for purposes of general education.

(5) Practical applications of scientific knowledge, in terms of a happy and useful life, are increasingly included in science courses for purposes of general education.

(6) There is a growing conviction among science instructors in general education that the way topics are dealt with is at least as important as the topics themselves. Instructors seem to feel that if

the ideas of science and its procedures are important, the topics must be dealt with in such a way that students will recognize other examples and applications of the ideas and procedures illustrated by a particular topic.

(7) Science instruction for purposes of general education is increasingly providing more opportunity for analysis and discussions by students.

It appears then that from the standpoint of the opportunity for students of general education to understand and practice the meaning of scientific methodology that explicit and direct attention should be given to developing the meaning of scientific methodology as it applies to the general student.

In summary, then, the literature of the past four and a half decades demonstrates that a great deal of work has been done in identifying the goals of science education. It also demonstrates that the stating of these goals has been an evolving and refining process which has progressed to the point where science is conceived as a process and as a field of human endeavor. Following very closely on the heels of science as a process was the realization that the process of science consisted of a complex set of abilities and attitudes which the student has to master if he is to be active in the inquiry process. At the present time, then, the goals of science education are to provide for the development of critical thinking abilities so that the student might be able to play the active role of the inquirer.

At the present time there are few instances of attempts to state the goals in behavioral terms, that is, there have been no advances in identifying and naming the observable act that will be accepted as evidence that the learner has achieved the objective.

It seems then that the next step in the evolution process would be that of selecting terminal behaviors and identifying and naming the observable act that will be accepted as evidence that the learner has achieved the objective.

CHAPTER III

PROCEDURES OF THE STUDY

Population

The population of this study consists of all the instructors in the institutions of higher education in the state of Missouri who have the responsibility for planning, organizing, operating, and evaluating the non-major general biology course.

A list of all institutions of higher education in the state of Missouri was obtained from two sources, The College Blue Book, 1969-70, Thirteenth Edition, 1969, and the American Junior Colleges, Seventh Edition, 1967. By cross checking these two sources a master list of 73 institutions was developed.

A letter was sent (Appendix A) to the academic dean of each institution on the master list asking him to provide the names of the instructors in his school who had the responsibility for some part of the non-major general biology course. Of the 73 institutions on the master list, 20 did not offer a general biology course, and 1 was closed. These 21 names were removed from the master list. The remaining 52 institutions were distributed as follows: 7 universities, 6 state colleges, 25 private liberal arts colleges, and 16 junior colleges.

From the 52 institutions which did offer a non-major general biology course the names of 104 instructors were obtained. These 104 individuals then became the population of this study to whom the personal data form and the questionnaire were sent.

The Instrument

The questionnaire was developed by the writer. From a review of four decades of literature concerning elementary, secondary, and collegiate science education related to the purpose of the laboratory a comprehensive outline of goals for science education was constructed.

Under each of the most specific subcategories of the outline one or more behavioral objectives were written. This initial formulation resulted in a comprehensive taxonomy of 182 behavioral objectives (Appendix B).

From the comprehensive taxonomy were chosen those statements which the author felt most adequately reflected the critical thinking and inquiry oriented learning outcomes of present science education philosophy regarding the laboratory.

The resulting questionnaire consisted of 85 behavioral objectives distributed among the following 11 major headings:

1.1 Ability to Formulate Significant Questions

1.2 Ability to Analyze Problems

1.3 Ability to Obtain from a Variety of Sources Information Regarding a Problem Statement

1.4 Ability to Devise Experiments Suitable to the Solution of a Problem

1.5 Ability to Criticize Faulty Experiments

1.6 Ability to Carry Out Experiments

1.7 Ability to Accurately Determine and Record Quantitative and Qualitative Data

1.8 Ability to Organize and Display Data

1.9 Ability to Interpret Data

2.0 Ability to Draw Conclusions

2.1 Ability to Communicate

Collection of Data

Data was collected by means of a questionnaire sent to each of 104 instructors of non-major general biology in the 52 institutions of higher education in the state of Missouri.

The questionnaire consisted of two parts (Appendix C). Part One was comprised of 22 items seeking information related to particular characteristics of the instructor, his education, and to particular characteristics of the institution. Part Two consisted of an 85-item questionnaire. The instructor was asked to express his opinion on each behavioral objective, by means of a five-point Likert type scale, in relation to the question, "To what degree do you feel that this statement is an important learning outcome for the laboratory of a non-major college level course in general biology?" The scale values ranged from 5 (very important) to 1 (not important).

Of the 104 questionnaires sent out 50 were returned for a 49 per cent return. Of the 50 returned the distribution according to type of institution was as follows: universities 3, state colleges 6, private liberal arts colleges 15, and junior colleges 7.

Analysis of Data

In developing the list of acceptable behavioral objectives as judged by the majority of the instructors a tally was made of every response to each behavioral objective. For each behavioral objective the number of responses in either the 5 and 4 categories were summed and divided by the total number of responses. If this value was equal to or larger than 50 per cent of the total responses then that behavioral objective was considered to be acceptable to the majority.

In order to determine any relationship between the characteristics of the instructors, their education, their institutions, or their program as it related to perceptions of the function of the non-major general biology laboratory, the Chi-Square for K Independent Samples was computed for each of the eleven sections of the questionnaire.

To obtain a frequency of response distribution for each section the choices 5 and 4 were considered as acceptance, the choice 3 was considered neutral and was dropped from further computations, while choices 2 and 1 were considered as non-acceptance. The total acceptance and non-acceptance responses for each instructor on each behavioral objective within a section were tallied. This procedure was followed for each instructor falling into a particular class and these were summed to give a frequency of acceptance and non-acceptance for each class of instructor for each section of the questionnaire.

The formula for Chi-Square used is given below:

$$X^2 = \sum_{i-1}^{r} \sum_{j-1}^{k} \frac{(O_{ij} - E_{ij})^2}{E_{ij}}$$

O_{ij} = observed number of cases categorized in the ith row of jth column.

E_{ij} = number of cases expected under H_o to be categorized in ith row of jth column.

$\sum_{i=1}^{r} \sum_{j=1}^{k}$ directs one sum over all (r) rows and all (k) columns, i.e., to sum over all cells

The values of Chi-Square yielded by the formula above are distributed approximately as Chi-Square with df = (r-1)(k-1), where r = the number of rows and k = the number of columns in the contingency tables. The symbol X^2 is used for the quantity in the above formula which is computed from the observed data when a Chi-Square test is performed. The words "Chi-Square" refer to a random variable which follows the Chi-Square distribution as given in Table C of Siegel (1956). The significance of the value obtained for X^2 will be determined by the use of Table C from Siegel. The statistical analysis will be given in Chapter IV.

CHAPTER IV

RESULTS OF THE STUDY

As indicated previously, the attempt was made to establish a list of behavioral objectives for the laboratory of a non-major general biology course which would be acceptable to a majority of the instructors responsible for such a course. Tables I and II contain the results of this attempt.

The attempt was also made to determine whether or not particular characteristics of the instructors, their education, or their institutions had any relation to their choice of those behavioral objectives. Tables III through XVII contain the results of this attempt. In all cases any Chi-Square value not significant at the .05 level was identified in the table as N.S., and any value greater than .05 was identified by the level at which it was significant. In all cases the number of individuals falling within a particular category are identified on the table under the heading N.

Table I indicates that 29 out of 85 or 34 per cent of the statements were judged acceptable by at least 50 per cent of the respondents and that no statement was acceptable to more than 76 per cent of the respondents.

Table II is the result of placing the 29 acceptable objectives back into their original sections. This reveals that six of the eleven sections had at least fifty per cent of the statements judged

TABLE I

BEHAVIORAL OBJECTIVES RANKED FROM MOST ACCEPTABLE TO LEAST ACCEPTABLE BASED ON PERCENT OF RESPONSE

Objective No.	Accept	Neutral	Reject	Objective No.	Accept	Neutral	Reject
8	76	20	4	69	42	34	24
71	76	18	6	54	42	32	26
82	74	20	6	80	42	30	28
37	74	18	8	39	42	22	36
5	72	28	0	50	40	44	16
81	72	20	8	46	40	40	20
6	70	24	6	77	40	36	24
72	70	18	12	62	40	34	26
36	68	24	8	28	40	32	28
4	66	28	6	32	40	28	32
83	66	24	10	45	38	48	12
24	64	26	12	51	38	32	30
11	62	30	8	63	38	32	30
2	62	20	18	15	38	30	32
12	60	28	12	17	38	28	34
29	60	24	16	13	34	36	30
35	58	34	8	16	34	30	36
7	58	34	8	40	34	26	40
33	58	26	16	49	30	48	22
25	56	32	12	48	30	46	24
3	56	32	12	67	32	48	20
27	56	24	20	73	32	42	26
21	54	32	14	70	32	36	32
9	52	34	14	76	30	42	28
44	52	34	14	42	30	20	50
55	52	30	18	18	28	46	26
26	52	32	16	19	28	46	26
84	50	28	22	75	26	42	32
10	50	36	14	20	24	38	38
78	48	34	18	47	22	42	36
1	48	26	26	57	22	32	46
34	46	44	10	59	22	28	50
53	46	36	18	60	22	24	54
30	46	36	18	58	22	16	62
66	46	32	22	68	20	28	52
31	46	30	24	43	20	16	64
85	46	28	26	65	18	38	44
38	46	28	26	79	14	40	46
56	46	28	26	22	14	34	52
64	44	36	20	23	14	24	62
52	44	34	22	74	12	26	62
14	42	40	18	41	12	20	68
				61	8	30	64

TABLE II

QUESTIONNAIRE SECTION ANALYSIS

Section No.	Number of Statements Per Section	Number of Statements Accepted Per Section	Per Cent of Statements Accepted
1.1	3	2	66
1.2	9	9	100
1.3	11	1	9
1.4	9	5	55
1.5	5	4	80
1.6	13	1	7
1.7	11	1	9
1.8	9	0	0
1.9	10	2	20
2.0	3	3	100
2.1	2	1	50

acceptable. Perhaps the most important observation is that five sections had 0 to 20 per cent of the statements judged acceptable. This would tend to indicate that these sections--1.3 Ability to Obtain Information Regarding a Problem Statement from a Variety of Sources, 1.6 Ability to Carry Out Experiments, 1.7 Ability to Accurately Determine and Record Qualitative and Quantitative Data, 1.8 Ability to Organize and Display Data, and 1.9 Ability to Interpret Data--were considered inappropriate for the non-major biology student.

Section 1.1 Ability to Formulate Significant Problems, 1.2 Ability to Analyze Problems, 1.4 Ability to Devise Experiments Suitable to the Solution of a Problem, 1.5 Ability to Criticize Faulty Experiments, 2.0 Ability to Draw Conclusions, and 2.1 Ability to Communicate, were deemed appropriate for the non-major biology student.

Table III shows that nine out of the eleven sections of the questionnaire had very highly significant differences among the four groups tested. Only in two of the sections, 1.8 and 2.0, could the results have been obtained by chance. It is quite clear from these figures that instructors from the university, the private liberal arts college, the state college, and the junior college in the sample have very different ideas on the learning outcomes of the laboratory of the non-major biology course.

Table IV indicates that in only two of the sections is there a significant difference between male and female instructors. In general, the sex of the instructor has only a very slight relation to the choice of behavioral objectives for the laboratory.

Table V indicates that the age of the instructor has a significant relation to the choice of behavioral objectives in that ten of the

TABLE III

COMPARISON OF RESPONSES TO EACH SECTION OF THE QUESTIONNAIRE BY INSTRUCTORS FROM UNIVERSITIES, PRIVATE LIBERAL ARTS COLLEGES, STATE COLLEGES AND JUNIOR COLLEGES

	1.1		1.2		1.3		1.4		1.5		1.6		1.7		1.8		1.9		2.0		2.1		
Subject	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	N
Universities	11	3	30	5	25	11	29	1	17	0	22	18	20	19	20	13	24	12	12	0	4	2	5
Private Liberal Arts	41	5	140	4	77	75	111	37	75	5	117	74	92	72	75	50	102	38	47	3	29	3	21
State Colleges	15	15	66	16	35	69	55	43	32	18	48	73	48	71	38	51	43	56	27	7	9	16	15
Junior Colleges	16	4	46	10	38	30	40	7	28	2	32	49	21	46	22	21	26	36	20	2	6	2	9
df	3		3		3		3		3		3		3		3		3		3		3		
X^2	15.44		19.03		17.26		26.32		27.99		18.76		14.43		7.06		28.96		6.38		19.35		
Significant at:	.01		.001		.001		.001		.001		.001		.01		N.S.		.001		N.S.		.001		

TABLE IV

COMPARISON OF RESPONSES MADE BY MALE AND FEMALE INSTRUCTORS
TO EACH SECTION OF THE QUESTIONNAIRE

	1.1		1.2		1.3		1.4		1.5		1.6		1.7		1.8		1.9		2.0		2.1		
Subject	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	N
Male	53	20	182	29	116	129	142	62	107	20	149	133	128	139	96	96	127	96	74	8	26	20	35
Female	30	7	100	6	59	56	93	26	45	5	70	81	53	69	59	39	68	46	32	4	22	4	15
df	1		1		1		1		1		1		1		1		1		1		1		
X^2	.953		4.70		.490		2.77		.977		1.65		.681		2.72		.225		.050		.590		
Significant at:	N.S.		.05		N.S.		N.S.		N.S.		N.S.		N.S.		N.S.		N.S.		N.S.		.02		

TABLE V

COMPARISON OF RESPONSES OF INSTRUCTORS IN AGE BRACKETS
25-30, 31-36, 37-42, 43-48, 49-54 AND 55-65

Subject	1.1		1.2		1.3		1.4		1.5		1.6		1.7		1.8		1.9		2.0		2.1		N
	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	
25-30	14	4	33	13	25	29	35	10	21	6	34	33	15	49	16	29	23	27	16	1	7	6	8
31-36	29	6	89	6	71	39	78	13	48	1	70	56	63	42	50	31	67	31	35	1	11	5	15
37-42	19	2	69	4	30	41	49	17	36	2	42	40	30	49	24	32	38	28	21	1	10	4	11
43-48	8	3	31	0	8	26	24	15	12	0	30	21	24	22	19	9	17	17	13	0	8	1	5
49-54	9	4	35	6	25	25	31	16	21	6	28	29	25	22	30	9	32	15	14	3	8	3	6
55-65	4	8	25	6	16	25	18	17	14	10	15	35	24	24	16	25	18	24	7	6	4	5	5
df	5		5		5		5		5		5		5		5		5		5		5		
X^2	15.46		24.91		22.55		19.96		28.26		11.17		25.36		24.95		14.08		24.20		5.32		
Significant at:	.01		.001		.001		.01		.001		.05		.001		.001		.02		.01		N.S.		

eleven sections were significantly different.

Table VI shows that six of the eleven sections were significantly different in relation to the number of years of previous high school teaching experience the instructor has had.

Table VII illustrates that the choice made on five of the eleven sections are different but since the numbers of respondees in the sample are so different and because those who are in the research group had so many 0 cells it was thought necessary to drop this question because of inadequate data.

Table VIII indicates the relatively small number of differences, four out of eleven sections, between the choices made by instructors holding the doctorate and those holding the master's degree. In general, it can be said that there is very little relationship shown.

Table IX demonstrates the relatively slight degree of relation which the type of institution in which the instructor earned his bachelor's degree has on the choice of behavioral objectives. Only three out of the eleven sections were found to be significantly different.

Table X illustrates that three of the eleven sections were significantly different in relation to the number of years the instructor has taught in the non-major biology course.

Table XI shows that instructors who chose to teach the general biology course and those who were assigned to teach the course differed significantly only on three of the eleven sections of the questionnaire.

Table XII illustrates the very small relation which having majors enrolled in the general biology course has to the choice of objectives made by the instructor with one of the eleven sections being

TABLE VI

COMPARISON OF RESPONSES MADE BY INSTRUCTORS WHO HAVE HAD 0 YEARS, 1-3 YEARS, OR 4 OR MORE YEARS OF HIGH SCHOOL TEACHING

	1.1		1.2		1.3		1.4		1.5		1.6		1.7		1.8		1.9		2.0		2.1		
Subject	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	N
0 Years	38	9	121	19	71	85	109	35	74	8	84	94	62	101	50	64	85	50	47	2	17	12	23
1-3 Years	18	8	58	10	32	56	37	32	31	2	59	45	34	55	30	40	38	40	27	0	11	6	11
4 or More Years	27	10	103	6	72	44	89	21	47	15	76	75	85	52	75	31	72	52	32	10	20	6	16
df	2		2		2		2		2		2		2		2		2		2		2		
x^2	1.41		5.24		14.29		17.06		8.24		2.40		20.46		20.13		4.12		13.60		2.11		
Significant at:	N.S.		N.S.		.001		.001		.02		N.S.		.001		.001		N.S.		.01		N.S.		

TABLE VII

COMPARISON OF RESPONSES MADE BY INSTRUCTORS WHO CONSIDER THEIR OWN PROFESSIONAL WORTH TO BE IN RESEARCH AND THOSE WHO CONSIDER IT TO BE IN TEACHING

	1.1		1.2		1.3		1.4		1.5		1.6		1.7		1.8		1.9		2.0		2.1		
Subject	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	N
Teaching	78	27	272	34	166	182	73	88	146	25	218	201	181	189	154	125	192	133	102	12	47	22	47
Research	5	0	11	1	9	3	10	0	6	0	1	13	0	19	1	10	3	9	4	0	1	2	3
df	1		1		1		1		1		1		1		1		1		1		1		
x^2	1.70		0.09		3.46		11.26		1.02		10.92		17.38		9.04		5.51		0.47		1.57		
Significant at:	N.S.		N.S.		N.S.		.001		N.S.		.001		.001		.01		.02		N.S.		N.S.		

TABLE VIII

COMPARISON OF RESPONSES BY INSTRUCTORS WHO HOLD A DOCTORATE
AND THOSE WHO HOLD A MASTER'S DEGREE

	1.1		1.2		1.3		1.4		1.5		1.6		1.7		1.8		1.9		2.0		2.1		
Subject	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	N
Doctorate	43	9	144	14	86	97	122	48	84	13	121	86	100	84	90	59	108	52	52	6	26	10	24
Master's	33	14	112	20	70	79	92	40	59	12	88	107	67	100	53	62	79	72	45	6	19	11	22
df	1		1		1		1		1		1		1		1		1		1		1		
x^2	2.16		2.75		.000007		0.1538		0.3963		7.144		7.11		5.36		7.47		0.056		0.596		
Significant at:	N.S.		N.S.		N.S.		N.S.		N.S.		.01		.01		.05		.01		N.S.		N.S.		

TABLE IX

COMPARISON OF RESPONSES MADE BY INSTRUCTORS WHO RECEIVED THEIR BACHELOR'S DEGREE FROM A UNIVERSITY, A PRIVATE LIBERAL ARTS COLLEGE, OR A STATE COLLEGE

	1.1		1.2		1.3		1.4		1.5		1.6		1.7		1.8		1.9		2.0		2.1		
Subject	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	N
University	31	14	107	19	64	79	91	46	58	16	86	88	65	88	54	62	74	56	40	7	13	9	21
Private Liberal Arts	30	5	100	6	65	53	80	17	51	1	70	68	53	71	51	32	65	37	32	1	21	5	15
State College	22	8	75	10	46	53	64	25	43	8	63	58	63	49	50	41	56	49	34	4	14	10	14
df	2		2		2		2		2		2		2		2		2		2		2		
x^2	3.11		5.26		3.01		7.43		9.91		.201		5.98		4.43		2.37		2.99		3.65		
Significant at:	N.S.		N.S.		N.S.		.05		.01		N.S.		.05		N.S.		N.S.		N.S.		N.S.		

TABLE X

COMPARISON OF RESPONSES MADE BY INSTRUCTORS WHO HAVE TAUGHT OR PARTICIPATED IN THE NON-MAJOR BIOLOGY COURSE FOR 1-3 YEARS AND THOSE WHO HAVE TAUGHT FOR 4 OR MORE YEARS

	1.1		1.2		1.3		1.4		1.5		1.6		1.7		1.8		1.9		2.0		2.1		
Subject	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	N
1-3 Years	23	3	64	8	34	42	64	10	36	6	46	50	24	60	27	43	44	27	22	1	7	6	11
4 or More Years	60	24	218	27	141	145	171	78	116	19	173	164	157	148	128	92	151	115	84	11	41	18	39
df	1		1		1		1		1		1		1		1		1		1		1		
X^2	3.11		.0004		.500		9.13		.0011		.349		13.89		8.21		0.622		1.06		1.17		
Significant at:	N.S.		N.S.		N.S.		.01		N.S.		N.S.		.001		.01		N.S.		N.S.		N.S.		

TABLE XI

COMPARISON OF RESPONSES MADE BY INSTRUCTORS WHO CHOSE TO TEACH THE GENERAL BIOLOGY COURSE AND THOSE WHO WERE ASSIGNED

	1.1		1.2		1.3		1.4		1.5		1.6		1.7		1.8		1.9		2.0		2.1		
Subject	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	N
Chose	50	17	186	19	103	128	137	51	102	14	153	112	135	119	97	90	124	83	68	5	28	17	30
Assigned	33	10	96	16	72	57	98	37	55	11	66	102	46	89	58	45	71	59	91	7	20	7	20
df	1		1		1		1		1		1		1		1		1		1		1		
X^2	.063		1.86		4.18		.0031		.750		14.00		12.89		0.5260		.916		.0055		1.07		
Significant at:	N.S.		N.S.		.05		N.S.		N.S.		.001		.001		N.S.		N.S.		N.S.		N.S.		

TABLE XII

COMPARISON OF RESPONSES MADE BY INSTRUCTORS WHO TEACH A GENERAL BIOLOGY COURSE IN WHICH BIOLOGY MAJORS ARE ENROLLED AND THOSE WHO TEACH A COURSE IN WHICH THERE ARE NO BIOLOGY MAJORS ENROLLED

	1.1		1.2		1.3		1.4		1.5		1.6		1.7		1.8		1.9		2.0		2.1		
Subject	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	N
Majors Enrolled	53	12	169	20	116	91	136	55	96	11	134	133	100	115	90	78	118	78	57	9	33	12	30
Majors Not Enrolled	32	15	121	15	64	96	102	33	61	14	96	81	88	93	65	57	81	65	52	3	19	10	21
df	1		1		1		1		1		1		1		1		1		1		1		
x^2	2.70		0.0165		9.29		0.7599		2.62		0.6992		0.1749		0.0024		0.7677		2.25		.5157		
Significant at:	N.S.		N.S.		.01		N.S.		N.S.		N.S.		N.S.		N.S.		N.S.		N.S.		N.S.		

significantly different.

Table XIII describes the small difference shown by those instructors who attempt to recruit majors from the non-majors and those instructors who make no conscious, purposeful attempt to do so. One of the eleven sections was chosen differently.

Table XIV clearly demonstrates that the number of students enrolled in the course in an academic year has a strong relation to the choice of objectives by the instructors who teach these courses. Eight of the eleven sections were shown to be significantly different.

Table XV indicates that the presence or absence of a graduate program in the institution in which the general biology course is offered has a relatively important relationship to the choice of behavioral objectives. Six of the eleven sections were shown to be significantly different.

Table XVI describes the very small relation between those instructors who teach a graduate level course and those who do not teach such a course. Only one of the eleven sections was found to be significantly different.

Table XVII is a compilation of the significant differences for each hypothesis as indicated on the horizontal rows and also for each section of the questionnaire as indicated in the vertical columns. The total number of significant differences per hypothesis are shown on the totals column on the right and the total number of significant differences per section are shown on the totals row at the bottom of the table.

The totals row at the bottom would indicate that sections 1.4, 1.6, and 1.7 had a high degree of disagreement among the respondents,

TABLE XIII

COMPARISON OF RESPONSES MADE BY INSTRUCTORS WHO TRY TO RECRUIT MAJORS FROM THE NON-MAJOR BIOLOGY COURSE AND THOSE WHO DO NOT TRY TO RECRUIT

	1.1		1.2		1.3		1.4		1.5		1.6		1.7		1.8		1.9		2.0		2.1		
Subject	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	N
Do Recruit	24	7	81	6	50	46	75	18	36	5	65	61	58	49	47	34	49	40	25	4	19	6	14
Do Not Recruit	59	20	192	29	125	139	160	70	116	20	154	153	123	159	108	101	146	102	81	8	29	18	36
df	1		1		1		1		1		1		1		1		1		1		1		
x^2	.0899		2.40		0.6318		4.101		.1637		.0725		3.496		.9460		.3905		.5527		1.501		
Significant at:	N.S.		N.S.		N.S.		.05		N.S.		N.S.		N.S.		N.S.		N.S.		N.S.		N.S.		

TABLE XIV

COMPARISON OF RESPONSES MADE BY INSTRUCTORS FROM INSTITUTIONS WITH 1-250, 251-500, 501-750, AND 750-1000+ STUDENTS ENROLLED IN THE NON-MAJOR GENERAL BIOLOGY COURSE IN AN ACADEMIC YEAR

	1.1		1.2		1.3		1.4		1.5		1.6		1.7		1.8		1.9		2.0		2.1		
Subject	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	N
0-250	53	8	184	7	103	102	138	44	95	8	141	112	117	103	98	66	126	60	64	4	32	7	28
251-500	9	0	19	4	10	21	25	5	14	0	15	18	5	29	9	10	17	12	10	0	4	1	4
501-750	9	7	31	3	23	23	33	12	13	2	16	42	18	37	17	22	14	31	10	2	5	7	8
751-1000	12	12	48	21	39	39	39	27	30	15	47	42	41	39	33	37	38	39	22	6	7	9	10
df	2		3		3		3		3		3		3		3		3		3		3		
x^2	18.81		38.12		3.63		8.783		19.432		15.477		22.681		5.540		22.949		6.940		11.710		
Significant at:	.001		.001		N.S.		.05		.001		.01		.001		N.S.		.001		N.S.		.01		

TABLE XV

COMPARISON OF RESPONSES MADE BY INSTRUCTORS FROM
INSTITUTIONS WHICH OFFER A GRADUATE PROGRAM IN
BIOLOGY AND THOSE INSTITUTIONS WHICH DO NOT

	1.1		1.2		1.3		1.4		1.5		1.6		1.7		1.8		1.9		2.0		2.1		
Subject	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	N
Graduate Program	25	15	87	18	58	71	77	40	49	13	64	82	65	74	56	52	62	61	37	6	13	14	18
No Graduate Program	94	12	195	17	117	108	158	48	103	12	155	132	116	134	99	83	133	81	69	6	35	10	32
df	1		1		1		1		1		1		1		1		1		1		1		
X^2	13.204		5.952		1.625		4.462		3.685		4.005		.0047		.1763		4.418		1.060		6.666		
Significant at:	.001		.02		N.S.		.05		N.S.		.05		N.S.		N.S.		.05		N.S.		.01		

TABLE XVI

COMPARISON OF RESPONSES MADE BY THOSE INSTRUCTORS WHO TEACH A GRADUATE LEVEL COURSE AND THOSE WHO DO NOT

	1.1		1.2		1.3		1.4		1.5		1.6		1.7		1.8		1.9		2.0		2.1		
Subject	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	Acc.	Rej.	N
Teach Graduate	12	6	40	13	25	41	43	24	29	6	41	31	34	32	31	24	41	21	20	3	8	7	10
Not Teach Graduate	71	21	242	22	150	144	192	64	123	19	178	183	147	176	124	111	154	120	86	9	40	17	40
df	1		1		1		1		1		1		1		1		1		1		1		
x^2	.897		11.786		3.726		3.137		.3277		1.400		.7941		.2319		2.045		.2583		1.516		
Significant at:	N.S.		.001		N.S.		N.S.		N.S.		N.S.		N.S.		N.S.		N.S.		N.S.		N.S.		

TABLE XVII

COMPILATION OF SIGNIFICANT DIFFERENCES FOR EACH HYPOTHESIS
AND FOR EACH SECTION OF THE QUESTIONNAIRE

Hypoth-esis	Questionnaire Sections											Total
	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	
1	.01	.001	.001	.001	.001	.001	.01	N.S.	.001	N.S.	.001	9
2	N.S.	.05	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	.02	2
3	.01	.02	.01	.001	.001	.05	N.S.	N.S.	N.S.	.001	N.S.	7
4	N.S.	N.S.	.001	.001	.02	N.S.	.001	.001	N.S.	.01	N.S.	6
5	N.S.	N.S.	N.S.	.001	N.S.	.001	.001	.01	.02	N.S.	N.S.	5
6	N.S.	N.S.	N.S.	N.S.	N.S.	.01	.01	.05	.01	N.S.	N.S.	4
7	N.S.	N.S.	N.S.	.05	.01	N.S.	.05	N.S.	N.S.	N.S.	N.S.	3
8	N.S.	N.S.	N.S.	.01	N.S.	N.S.	.001	.01	N.S.	N.S.	N.S.	3
9	N.S.	N.S.	.05	N.S.	N.S.	.001	.001	N.S.	N.S.	N.S.	N.S.	3
10	N.S.	N.S.	.01	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	4
11	N.S.	N.S.	N.S.	.05	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	1
12	.001	.001	N.S.	.05	.001	.01	.001	N.S.	.001	N.S.	.01	8
13	.001	.02	N.S.	.05	N.S.	.05	N.S.	N.S.	.05	N.S.	.01	6
14	N.S.	.001	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	1
Total	4	6	5	9	5	7	8	4	5	2	4	

while the differences in the remaining eight sections were relatively small and uniform with six of the remaining eight sections having either four or five differences and the remaining two having six and two differences each. This would indicate that the questionnaire was fairly reliable and that the results obtained were not due to any idiosyncracies of the questionnaire.

The total significant differences per hypothesis as shown in the total column at the right illustrate that five of the fourteen hypotheses--1, 3, 4, 12, and 13--show a high significant difference, having at least six of the eleven sections of the questionnaire as significantly different. The remaining nine hypotheses--2, 5, 6, 7, 8, 9, 10, 11, and 14--having from one to five sections significantly different can be considered as having shown no to slight relationship to the choice of the behavioral objectives.

Summary of Findings

The results of this study as shown by Tables I and II, pages 79 and 80, indicate that twenty-nine out of eighty-five behavioral objectives of the study were judged to be acceptable learning outcomes of the laboratory of a non-major general biology course by at least fifty per cent of the respondents. In no instance was a behavioral objective judged acceptable by more than seventy-six per cent of the respondents.

It was also shown that certain sections of the questionnaire had no behavioral objectives judged acceptable indicating a general agreement across all segments of the population that these sections (goals) are thought inappropriate for the non-major student.

The results also indicate, as shown by Tables III through XVII, that five out of the fourteen characteristics of the instructor, his education, and his institution are highly significant in relation to what he perceives as the function of the laboratory of a non-major college level biology course. Three of the five characteristics found significant were related to the institution itself, that is, the type of institution, the number of students enrolled in the general biology course, and the presence or absence of a graduate program in the biology department. One of the five significant hypotheses relates to a characteristic of the instructor, that is, his age, and one relates to a characteristic of the instructor's education and experience, that is, the number of years of previous high school teaching experience he has had.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

This study was made in an attempt to develop a list of behavioral objectives for the laboratory portion of a non-major general biology course which would be acceptable to a majority of the instructors teaching such a course.

It was also the purpose of this study to determine whether or not particular characteristics of the instructor, his education, or his institution had any relation to his perception of the function of the laboratory and consequently to his choice of the specific learning outcomes of the laboratory. The data would indicate that it is possible to establish a list of learning outcomes of the laboratory which would be acceptable to a majority of instructors with widely varying backgrounds and characteristics.

Because of space limitations only the number of the objective will be included here and the interested reader can refer to the questionnaire itself in Appendix C. The following behavioral objectives were judged as acceptable learning outcomes of the laboratory of a non-major general biology course: 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 21, 24, 25, 26, 27, 29, 33, 35, 36, 37, 44, 55, 71, 72, 81, 82, 83, and 84.

Based on Chi-Square statistical analyses the following five hypotheses cannot be accepted.

1. There will be no difference in the choice of behavioral objectives by instructors in universities, private liberal arts colleges, state colleges, and junior colleges.
3. There will be no difference in the choice of behavioral objectives by instructors who are in the age brackets 25-30, 31-36, 37-42, 43-48, 49-54, 55-65.
4. There will be no difference in the choice of behavioral objectives by instructors who have had 0 years, 1-3 years, or 4 or more years of high school teaching experience.
12. There will be no difference in the choice of behavioral objectives by instructors whose general biology course enrolls 1-250, 251-500, 501-750, 751-1000 students per year.
13. There will be no difference in the choice of behavioral objectives by instructors whose department offers a graduate program in biology and those whose departments do not have a graduate program.

The following eight hypotheses are held to be tenable and will be accepted.

2. There will be no difference in the choice of behavioral objectives by instructors who are female and those who are male.
6. There will be no difference in the choice of behavioral objectives of instructors whose highest earned degree is the doctorate and those whose highest earned degree is the master's degree.
7. There will be no difference in the choice of behavioral objectives by instructors who earned their bachelor's degree

in a university, a private liberal arts college, or a state college.

8. There will be no difference in the choice of behavioral objectives by instructors who have taught the non-major biology course 1-3 years and those who have taught it four or more years.

9. There will be no difference in the choice of behavioral objectives by those instructors who chose to teach the course and those who were assigned to teach it.

10. There will be no difference in the choice of behavioral objectives by instructors who have majors enrolled in the course and those who do not have majors enrolled.

11. There will be no difference in the choice of behavioral objectives by instructors who hope to recruit new majors from the students enrolled and those who do not hope to recruit.

14. There will be no difference in the choice of behavioral objectives by those instructors who teach a graduate course and those who do not teach a graduate course.

Because of insufficient data the following hypothesis cannot be answered.

5. There will be no difference in the choice of behavioral objectives by instructors who view their major professional function as teaching and those who view their major professional function as research.

Recommendations for Further Study

This is an exploratory study and as such raises as many questions as it answers. A study of this sort can isolate and make visible major areas of difficulty while at the same time identify those areas of a problem which are probably not significant and would not lead to further productive examination. In this light then, the following comments and recommendations are made.

1. It is quite clear that the choice of and importance put on the learning outcomes stated in the questionnaire were strongly related to the type of institution, the size of the class, and the absence or presence of a graduate program. This is not to say that an institution because of type, size, or program is better than or poorer than another but simply that it is different. If one assumes that what the instructor believes to be important will ultimately be shown by the kind of class he offers, it then follows that the kinds of laboratories required of the non-major student will be as significantly different as the instructors who planned them. The differences in the courses will not be related to anything as grandiose as curriculum planning but to the type of institution, the size of the student enrollment in that class, and to the presence or absence of a graduate biology program.

Studies related to size of the institution seem especially important at this period in higher education when the large institutions are becoming larger and the smaller ones are becoming smaller and with little known of the effect of this on learning outcomes.

In addition, state-wide planning and coordination, certification agencies, standardized testing agencies, state teacher certification agencies, college credit transfer agencies, and a host of other agencies and groups all generally accept the notion that what a student gets from one institution in General Biology is what he would have gotten from any other institution offering a course with the same name. This more than likely is not the case.

It seems then that studies should be made which would attempt to identify those characteristics related to type of institution, size of enrollment in a class, and the presence or absence of a graduate degree program which cause, force, permit, or contribute to an instructor's putting a specific value on a specific learning outcome.

2. It is also evident that one's age has a significant relationship to the choice of and value applied to the learning outcomes of the questionnaire. It is difficult to see without going deep into personal histories how these could be related since the data has also shown that highest degree earned, type of institution where undergraduate degree earned, how long one has taught the general biology course, and whether one chose to or was assigned to teach the courses, has little or no relationship to the choice of learning outcomes.

3. It is also true that whether or not an instructor has had previous high school teaching experience has a significant relationship to the choice of learning outcomes of the laboratory.

Because of the recent interest in the quality of college teaching and the current literature regarding the pre-service preparation of college teachers, it would seem profitable to investigate this area more fully.

If one were to look into this problem it might be profitable to see how the people with high school experience got into college teaching. The National Science Foundation summer and academic year programs for high school teachers have given tremendous impetus for many people to get their master's degree, eventually their doctorate, and eventually to go into college teaching. It would seem to be necessary to determine to which type of institution these people go. Information gained here might be useful in helping to devise a program for pre-service preparation of college teachers.

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APPENDIX A

INITIAL LETTER

April 28, 1971

In an attempt to assess the level of agreement on the function of the introductory general education biology laboratory in the institutions of higher education in Missouri, it is necessary for me to contact every instructor responsible for planning, organizing, operating, and evaluating the course which may, or must, be taken by the non-major.

I am hoping to enlist your aid by your supplying the following information regarding each instructor as described above.

Name

School mailing address

Highest degree now held

Office phone number

It would be greatly appreciated if this information could be in my hands by May 15, 1971.

If you would be interested in the results of this study, I would be more than happy to send them. Just make a note on the return letter.

Thank you.

/s/ Gary D. Jensen

Gary D. Jensen
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APPENDIX B

BEHAVIORAL OBJECTIVES FOR THE LABORATORY OF A NON-MAJOR COLLEGE LEVEL COURSE IN GENERAL BIOLOGY

BEHAVIORAL OBJECTIVES FOR THE LABORATORY OF A NON-MAJOR COLLEGE LEVEL COURSE IN GENERAL BIOLOGY

1.0 Interests

- 1.1 Acquires an appetite for scientific reading.
  - 1.11 Given a list of biology related books the student will have voluntarily purchased at least two from the bookstore.
  - 1.12 The student will upon invitation volunteer to serve as the reporter of current political and social matters relating to biology.
- 1.2 Acquires an interest in taking more biology.
  - 1.21 The student will upon invitation enroll for a second course in biology.
- 1.3 Acquires an interest in nature which may be used as a recreational activity or hobby.
  - 1.31 The student will upon invitation participate in at least one departmental sponsored overnight camping trip.
  - 1.32 The student will upon invitation participate in at least one departmental sponsored field trip.
  - 1.33 The student will upon invitation participate in at least one departmental sponsored vacation period trip to a site of significant biological research.
  - 1.34 The student will upon invitation voluntarily participate in the operation of a science fair.
  - 1.35 The student will upon invitation volunteer to serve as a merit badge counsellor in biology for the Boy Scouts.
  - 1.36 The student will upon invitation volunteer to participate in the operation of a blood bank drive.
  - 1.37 The student will upon invitation volunteer to participate in the operation of a local public school immunization program.
  - 1.38 The student will upon invitation avail himself of the opportunity to rent at least one "living" display unit sponsored by the biology department.
  - 1.39 Given a list of ten science related activities and asked to rate each one as either: do enjoy, uncertain, don't enjoy, never performed, the student will rate at least five as enjoyable.
- 1.4 Acquires an interest in biology as a possible field for a vocation.
  - 1.41 The student will upon invitation voluntarily browse the biology career section of the biology library.

1.42 The student will when supplied with the necessary information regarding biology related summer jobs, seek to gain such employment.
1.43 The student will when supplied with a list of characteristics of various types of life work, show a preference for those based on other than expected earning power.

2.0 Ideals and Habits
2.1 Develops a rationale as to the place of the scientifically literate person in a democracy.
2.11 Given a list of statements relating some application of a scientific or technological advancement to society's use, such as: "every citizen should support measures that provide for public health facilities even though these would raise taxes", and asked to rate each statement as agree, uncertain, or disagree, the student will agree with at least fifty percent of them.
2.12 When given an assignment of a term paper in which the student is to relate one or more theories of biology to his personal ethical standards and personal goals the student will demonstrate the relationship.
2.13 When supplied with a list of political or social issues, problems, or events which are related to science such as bills passed by Congress the student will upon invitation write to a responsible official regarding his feelings on the matter.
2.14 Shown a series of 35mm slides of science related impressionistic art the student will be able to identify the scientific concept being portrayed.
2.15 Upon invitation the student will participate in a discussion of social problems in terms of the relationship of science and technology.
2.16 Given a series of value laden statements related to biology such as: "the mother of the year should have two adopted children and none of her own", and asked to rate each as accept, uncertain, or reject, the student will accept at least fifty percent.
2.17 Given a series of statements regarding various phases of health such as: "requiring a premarital physical examination is not part of the natural way mating should take place", and asked to rate each as either agree, uncertain, or disagree, the student will demonstrate the proper attitudes toward personal and public health practices.
2.18 Given the invitation to participate in one or more projects lasting over a period of weeks and related to the ecology or health of the community the student will do so.
2.2 Develops a faith in the logical processes of science and uses its modes of inquiry.
2.21 Given a list of definitions of the term biology the student will show preference for those that indicate biology as an enterprise of human beings that depends

as much on its inquiry as it does on its conceptual patterns.

2.22 Given a series of statements which have either a rational, scientific basis or an irrational superstitious basis the student will show preference for those which are rational and scientific based.

2.23 When writing a book report the student will without being asked consider those characteristics which make it logically sound.

2.24 Given a problem and a series of possible answers the student, when asked to rank the answers from best to worst, will rank them in such a manner as to show preference for answers based on experimental evidence.

2.25 When participating in a sociodrama or role playing episode designed to present conflict between reason and the methods of experimentation and rationalization and emotion the student will defend reason and experimentation.

2.26 Given a description of a situation in which a technological advance has created problems affecting society, the student will identify the problems involved and the scientific principles that are related to the problems and will suggest a plan for solving the problems that were identified (e.g., the ecological problems caused by DDT).

3.0 Attitudes

3.1 The attitude of looking for the natural cause of things that happen.

3.11 Attitude of believing that occurrences which seem strange and mysterious can always be explained fully by natural causes.

3.111 Given a phenomenon which seems strange and unexplainable and a series of possible explanations the student will rank highest those explanations most nearly related to natural causes.

3.12 Attitude of believing that there is necessarily no connection between two events just because they occur at the same time.

3.121 Given a series of paired events and directed to rate them on the following basis: definitely connected events, probable connected events, probable non-connected events, or definitely non-connected events, the student will do so with 90 percent accuracy.

3.13 Attitude of believing in the universality of cause and effect relationships.

3.131 Given the statement: "everything is caused", the student will defend the statement and will provide at least three examples of cause and effect relationships.

3.2 The attitude of being open minded toward work, opinions of others, and information related to a problem.

3.21 Attitude of basing ideas upon the best evidence and not upon tradition alone.

3.211 Given a proposition to either reject with cause or accept with cause the student will do so by citing evidence from at least four different authors.

3.22 Attitude of being willing to revise his opinions and conclusions in light of additional reliable information.

3.221 Given a situation involving at least two alternatives (e.g., increased ratio of fresh water clams to fresh water snails: increased tolerance to pollution? or new food source?), the student will formulate and defend a procedural method by which he arrives at his tentative decision.

3.222 The student having formulated and defended a procedural method by which he arrived at a tentative decision, upon being presented additional information is then willing to reconsider and reformulate his decision.

3.223 Given a situation involving three variables, the student will formulate a response which is factually correct based on experimental evidence.

3.23 Attitude of being willing to listen to, observe or read evidence supporting ideas contrary to his personal opinions.

3.231 In a group discussion the student will listen to and pay attention to other members of the group whose opinions differ from his own.

3.24 Attitude of accepting no conclusion as final or ultimate.

3.241 Given one or more paragraphs from the publication of some special interest group, e.g., soap manufacturers, auto manufacturers, the student will identify those statements which are designed to show only one side of the problem if indeed they do exist.

3.25 Open minded willingness to investigate any problem by the objective method wherever necessary.

3.251 Upon invitation the student will participate in the operation of a biology department sponsored research project.

3.252 Given directions to do so the student will identify at least three researchable problems a week from his daily life.

3.26 Attitude of attempting to secure accurate information as a basis for logical decisions.

3.261 In group discussions the student will ask pertinent questions which indicate the wish for further information.

3.3 Attitude of using care in drawing conclusions.

3.31 Attitude of limiting conclusions to data at hand.

3.311 Given a table of data and a series of conclusions and asked to rate the conclusions on the following basis: data upholds the conclusion, data inadequate to make this conclusion, or data refutes the conclusion, the student will do so with 90 percent accuracy.

3.32 Recognizing the possibility of and guarding against sources of error.

3.321 While participating in a sociodrama or role playing situation in which the student is given the responsibility for making the proper decision after listening to the arguments of three other participants who are each attempting to cause the decision to be in their favor, the student will be able to identify those arguments in which there is insufficient evidence presented, those arguments where selected or unrepresentative examples are used, those arguments where unreliability of testimony is seen, and those arguments where neglect of negative evidence is found.

4.0 Abilities

4.1 Ability to formulate significant problems.

4.11 Ability to sense a problem and make a decision to find an answer.

4.111 Ability to sense situations involving personal and social problems.

4.1111 The student, when directed to do so, will be able to describe in written form, at least three problems within a week period, which are of importance to him. The statement will consist of a concise description of the situation, the probable contributing factors, and a possible method of solution.

4.112 Ability to recognize a problem or perplexity in the context of a paragraph or an article.

4.1121 Given a paragraph or an article of a descriptive nature as found in popular literature (e.g., Ardery, Robert. "Is Man Naturally Violent?" Readers Digest, Dec., 1970, pp. 115-119), the student will be able to identify in a written form from one to three significant problems found in the material. The statements will consist of a concise description of the situation, the probable contributing factors, and a possible method of investigation.

4.113 Ability to recognize a problem or perplexity in the context of a situation.

4.1131 Given a living population (balanced aquarium, earthworms, spiders, cockroaches, white mice, ants, meal worms, Daphnia, Drosophila, etc.) and directed to identify at least ten problems or questions raised by observing the population for one month, the student will be able to do so.

4.2 Ability to analyze problems.

4.21 Ability to delimit a problem.

4.211 Ability to analyze a problem into its essential parts.

4.2111 Given a complex problem made up of at least three separate problems (e.g., stream fish kill: local economics, local agricultural activity, local industry, local sewage treatment), the student will be able to isolate the separate problems.

4.212 Ability to isolate a single major problem or single major idea in a problem.

4.2121 Given a description of a situation (e.g., when the aerator stops working the snails begin to migrate to the upper part of the aquarium) the student will be able to identify at least three possible causative factors and to choose the most probable.

4.2122 Given quantitative data summarized in tables and graphs the student will be able to construct one or more inferences consistent with the data.

4.213 Ability to pick out the key words of a problem statement.

4.2131 The student will be able to identify and name properties of an object or situation by using at least four of the senses.

4.2132 The student will be able to distinguish between operational definitions and non-operational definitions of the same thing.

4.2133 Given an operational definition the student will be able to distinguish or identify an object or event from among a group of similar objects or events.

4.2134 The student will be able to construct an operational definition based on a classification scheme.

4.2135 The student will be able to construct an operational definition of an object from a multistage classification of a set of objects which includes the object to be defined.

4.2136 The student will be able to construct an operational definition which adequately describes a procedure, object, or property of an object in the context in which it is used.

4.2137 Given a hypothesis, inference, question, graph, or table of data, the student will be able to identify variables or words for which an operational definition is needed.

4.214 Ability to state a problem in question form.

4.2141 The student will be able to demonstrate the use of one or more operational definitions in the statement of a problem.

4.3 Ability to obtain information regarding a problem statement from a variety of sources.

4.31 Ability to locate source materials.

4.311 Ability to use the various parts of a book.

4.3111 Given a problem statement the student will be able to pick out the key words and locate the related material in the index of a specified text.

4.3112 Given a problem statement the student will be able to pick out the key words and locate the related material from the table of contents, glossary, figures, pictures and diagrams, topical headings and appendix of a specified text.

4.312 Ability to use materials other than text books.

4.3121 Given a problem statement the student will be able to pick out the key words and locate related materials in encyclopedias and dictionaries.

4.3122 Given a problem statement the student will be able to pick out the key words and locate related material in any one of the following: <u>Biological Abstracts</u>, <u>The Handbook of Biological Data</u>, annual index of <u>Science</u>, annual index of <u>Scientific American</u>.

4.313 Ability to use library facilities.

4.3131 Given a bibliographic citation the student will be able to use the card index to locate the call number of the book cited.

4.3132 Given a call number the student will be able to locate the book in the library.

4.3133 Given a problem statement the student will be able to locate related material by using the <u>Readers Guide to Periodical Literature</u>.

4.3134 The student will be able to locate and list the titles of all the journals related to biology carried by the library.

4.3135 Given a problem statement the student will be able to pick out the key words and locate materials in the library's microfilm holdings.

4.3136 Given a bibliographic citation of a journal article the student will be able to identify the author, journal title, article title, the year and month published, and the page on which the article begins and ends.

4.32 Ability to use aids in comprehending material read.

4.321 Ability to skim for main ideas.

4.3211 Given a problem statement and a journal article of not more than five pages the student will within five minutes be able to skim the material and evaluate its relevancy to the problem statement.

4.322 Ability to find the main ideas in a paragraph.

4.3221 Given a paragraph to read the student will be able to identify from a list of statements those which are related to the main ideas of the paragraph.

4.323 Ability to make outlines of reading.

4.3231 Given an article of no less than five pages the student will be able to outline the material correctly identifying major topics and ideas and the subtopics under each of the major topics.

4.3232 Given three articles with closely related content, each no less than five pages long, the student will be able to develop a single outline which will contain the major topics and subtopics of all three articles.

4.3233 Given an outline of a broad topic and an article which is much more restricted in scope but whose content fits within the broader topic the student will be able to incorporate the material of the article into the broader outline.

4.324 Ability to take notes.

4.3241 Given a written report of a research project the student will be able to write an abstract of the article.

4.33 Ability to interpret graphic material.

4.331 Ability to obtain information from different kinds of graphic materials.

4.3311 Given a table of paired events the student will be able to identify the dependent (responding) variables and the independent (manipulated) variable.

4.3312 Given a table of paired events the student will be able to construct a 20-30 word statement which describes the response of one variable to the manipulated variable.

4.3313 Given a frequency distribution the student will be able to construct a 20-30 word statement regarding the information provided by the graph.

4.3314 Given a graph the student will be able to identify the relationship between the dependent and independent variable as either linear or nonlinear and will be able to describe the information provided by the graph.

4.3315 Given a table of grouped data the student will be able to identify the range, and the class interval size.

4.3316 Given the mean, mode, median, range and frequency distribution of a set of measurements the student will be able to describe in a 20-30 word statement the quantity or object being measured.

4.3317 The student will be able to define the terms, sample variance, standard deviation, standard error of the mean, and correlation.

4.332 Ability to read titles, column headings, legends, and data recorded.

4.3321 Given a properly drawn and labeled graph on semilog graph paper the student will be able to identify the independent and dependent variable and construct a 20-30 word description of the information contained in the graph.

4.3322 Given a properly labeled graph the student will be able to describe the probable experimental procedure used to gain the information.

4.3323 Given a properly drawn and labeled graph the student will be able to make predictions by extrapolating beyond the range of observed events.

4.3324 Given a properly drawn and labeled graph the student will be able to make predictions by interpolating between observed events.

4.333 Ability to evaluate conclusions based upon the data recorded.

4.3331 The student will be able to distinguish between predictions that have been supported and predictions that have been refuted on the basis of data obtained from observations from a test of the predictions.

4.34 Ability to make observations suitable for solving a problem.

4.341 Ability to pick out the important ideas presented by pictures, slides and motion pictures.

4.3411 Given a problem statement and a series of 35mm slides, or a series of photographs, or a motion picture related to the problem, the student will be able to write a 20-30 word description of the relationship between the visual and the problem statement.

4.342 Ability to pick out the important ideas presented by models and exhibits.

4.3421 Given a problem statement and a model or exhibit related to the problem, the student will be able to write a 20-30 word description of the relationship between the visual and the problem statement.

4.35 Ability to use the resources of the community for purposes of obtaining information pertinent to a problem.

4.351 Ability to locate conditions or situations in the community to observe.

4.3511 Given a problem statement the student will be able to locate and describe at least one situation or condition in the community relevant to the problem.

4.352 Ability to pick out the essential ideas from observations.

4.3521 Given a problem statement and a situation or condition in the local community relevant to the problem the student will be able to write a 20-30 word description illustrating the relationship of his observations to the problem statement.

4.353 Ability to select individuals who can contribute to the solution of a problem.

4.3531 Given a problem statement the student will be able to list those individuals in the community who by training, experience, or interest may contribute to the solution of the problem statement.

4.36 Ability to recognize and accumulate facts related to the solution of a problem.

4.361 Ability to select the kind of information needed to solve a problem.

4.3611 Given a problem statement the student will be able to develop an index card file of no less than twenty different entries related to the problem statement. Each entry will have complete bibliographic information and an abstract of no less than 100 words.

4.362 Ability to recognize valid evidence.

4.3621 Given a properly drawn and labeled graph and two different interpretations of the information it contains the student will be able to identify the more valid of the two interpretations by describing the weaknesses of the improper interpretations.

4.363 Ability to differentiate between reliable and unreliable sources of information.

4.3631 Given a problem statement and a list of individuals who could possibly provide reliable information for its solution, the student will be able to correctly rank these individuals from most to least reliable.

4.3632 Given a problem statement and a list of journals the student will be able to correctly rank these journals from most to least reliable as sources of information in the solution of the problem statement.

4.3633 Given a problem statement and a list of books the student will be able to correctly rank these books from most to least reliable as sources of information in the solution of the problem statement.

4.364 Ability to select between data pertinent to the solution of a problem and that which is unrelated.

4.3641 Given an hypothesis, a table of data, and a conclusion supporting the hypothesis, the student will be able to evaluate the conclusion as correct or incorrect on the basis of the data.

4.4 Ability to devise experiments suitable to the solution of a problem.

4.41 Ability to select the most reasonable hypothesis to test.

4.411 Given a problem statement and a series of hypotheses, the student will be able to correctly rank the hypotheses from most reasonable to least reasonable.

4.42 Ability to differentiate between an uncontrolled observation and an experiment involving controls.

4.421 Given a table or graph of data the student will be able to identify the manipulated variable and the responding variable.

4.422 Given a problem statement and a hypothesis the student will be able to identify the dependent and the independent variable.

4.423 Given a problem statement and a hypothesis the student will be able to identify several factors which may influence the behavior or properties of the dependent and independent variables.

4.424 Given a factor in an experiment the student will be able to suggest means for holding that factor constant.

4.425 Given a description of the relationship between two variables the student will be able to construct a generalized graph and name the dependent and independent variable.

4.426 Given a properly drawn and labeled graph of the relationship between two variables the student will be able to predict the effect of altering an experimental condition, identify and name the variables that should be held constant, the one that should be manipulated, and the one that should be allowed to respond under the altered condition.

4.43 Ability to design an experiment.
   4.431 Given an inference based on a set of observations the student will be able to design an experiment which has an overall control, a manipulated variable, and a responding variable.
   4.432 Given a prediction based on interpolation or extrapolation from a table of data the student will be able to design an experiment which has an overall control, a manipulated variable, and a responding variable.

4.44 Ability to decide upon the kinds of evidence which should be collected.
   4.441 Given an inference and a test of that inference the student will be able to describe observations that would support the inference and observations that would refute the inference.
   4.442 Given a prediction and a test of that prediction the student will be able to describe observations that would support the prediction and observations that would refute the prediction.
   4.443 Given an hypothesis and an experimental design to test it the student will be able to construct properly labeled tables for the collection of data.

4.45 Ability to choose reliable methods of collecting the evidence.
   4.451 Given a problem statement, an hypothesis, and an experimental design, the student will be able to locate in the literature possible procedures for gathering data.
   4.452 Given a properly labeled data table and a list of test procedures the student will be able to identify those tests which will produce the type of data required.

4.5 Ability to criticize faulty experiments.
   4.51 Given an improperly designed experiment which could not test the specific hypothesis as stated the student will be able to identify it as improperly designed and will be able to incorporate the needed changes.
   4.52 Given an experimental design in which the method of collecting the data was unreliable the student will be able to identify the fault and will be able to incorporate the needed changes.
   4.53 Given an experiment in which the data were not accurate the student will be able to identify the fault and suggest a remedy.
   4.54 Given an experiment in which the data were insufficient in number the student will be able to identify the shortcoming and suggest a remedy.
   4.55 Given an experimental design in which proper controls were not included the student will be able to identify the fault and incorporate the needed changes.

4.56 Given an experimental design in which there were no controls included the student will be able to identify the fault and incorporate the needed changes.

4.6 Ability to carry out an experiment.

4.61 Ability to manipulate the laboratory equipment needed in solving a problem.

4.611 Given a properly written experimental procedure the student will be able to choose, set up, and operate all equipment needed.

4.612 Shown a series of 35mm slides of common laboratory equipment, the student will be able to correctly name 100 per cent of them.

4.613 Given any one of the following pieces of equipment and the operating instructions the student will be able to demonstrate the proper technique for its use: Spectrophotometer 20, student grade microscope with low, high and oil objectives, variable magnification stereoscope, two phase liquid chromatograph, electric balance, thermometer, magnetic stirrer, triple beam balance, dissecting set, bacterial colony counter, pH meter, bunsen burner, hot plate, table top centrifuge.

4.614 Given any one of the following experimental organisms and adequate directions the student will demonstrate competence in the proper handling, housing, and feeding of them by maintaining at least one group for at least two months: hamsters, gerbils, at least four freshwater invertebrates, white mice, white rats, frogs, turtles, spiders, roaches, ants, Drosophila, meal worms, bacteria, chicks, fish, plants.

4.615 Shown a series of 35mm slides the student will be able to identify by name, describe the purpose of, and describe the general functioning of the following pieces of research equipment: electron microscope, oscilloscope, X-ray machine, computer, Warburg type respirometer, Physiograph, refrigerated centrifuge, gas chromatograph, infrared spectrometer, phase microscope, autoclave.

4.616 The student will be able to use any piece of volumetric glassware with no more than $\pm$ 1 per cent error.

4.617 Given any one of twenty common acids, bases, or salts, either solid or liquid, the student will be able to demonstrate the proper method of dispensing, measuring and using it.

4.62 Ability to appraise scales and divisions of scales on measuring devices.

4.621 Given the scale which might be found on any instrument used to measure length, mass, time, volume, or temperature, the student will be able to correctly identify a marked point on the scale and name the units in which the measurement is taken.

4.622 Given any value of measurement of length, mass, time, volume, temperature, or quantity, the student will be able to convert it to any other value of the same unit (e.g., grams to milligrams, millimeters to Angstroms, etc.).

4.623 Given any change rate the student will be able to convert these values to any other value of the same units (e.g., miles per hour to feet per second, milliliters per minute to liters per hour, etc.).

4.624 Given any one of twenty common acids, bases, salts or elements the student will be able to correctly make a solution of specified normality, molarity, molality, or percentage by weight or volume, in the volume required by an experimental procedure.

4.625 Given a scale found on any instrument used to measure length, mass, volume, time, temperature, or quantity, the student will be able to name the most accurate measurement of which that instrument is capable.

4.626 Given at least three circumstances to be measured in each of the following areas: length, mass, time, volume and temperature, time and quantity, the student will be able to measure each circumstance at least ten times and obtain results within 1 per cent of the actual measurements each time.

4.63 Ability to recognize the existence of errors in measurement.

4.631 Ability to recognize when the precision of measurement given is warranted by the nature of the problem.

4.6311 Given an experimental procedure and the measuring instrument to be used the student will be able to identify the most precise measurement of which the instrument is capable and evaluate its usefulness to the experimental procedure.

4.6312 Given some quantitative experimental results and the scale of the measuring device used to obtain the results, the student will be able to evaluate the correctness of the precision of the data.

4.64 Ability to make accurate observations.

4.641 Shown a film loop of a color change taking place in a test tube, the student will be able to accurately describe the change.

4.642 Shown a film loop of a growth process the student will be able to accurately describe the changes taking place.

4.643 Given a series of microscope slides of serial sections of an organ the student will be able to accurately describe the changes taking place.

4.644 Given a series of quantitative values from a single event over time the student will be able to accurately describe the changes.

4.645 Shown a film loop of the movement of a freshwater invertebrate the student will be able to describe the path, rate, and direction of movement and the attitude of the body in the water.

4.646 Given a series of at least five study skins of birds the student will be able to construct a one, two, or multistage classification scheme and name the observable characteristics upon which the classification is based.

4.647 Given a dichotomous key and a set of objects the student will be able to identify any one of the objects.

4.65 Ability to observe similarities in situations which are different.

4.651 Given two different situations which have at least one similarity (e.g., growth of bacterial culture and growth of other populations; function of green gland and function of kidney; linear data from different experiences), the student will be able to describe the similarities.

4.652 Given a properly written experimental procedure to be used on a specific experimental subject, the student will be able to suggest how the same procedure could be used to accomplish the same thing in a different organism (e.g., auxin application to Coleus and to a liverwort, etc.).

4.66 Ability to observe differences in situations which are similar.

4.661 Given two similar situations which have at least one difference (e.g., phototaxis of Daphnia and phototropism of plants; skeletal structures of whale and bat, dental formula of carnivores and herbivores), the student will be able to describe the differences.

4.662 Given a properly written experimental procedure to be used on a specific experimental subject, the student will be able to identify those factors which will have to be accounted for in applying the procedure to a different experimental subject (e.g., nutritional regime to white rats and hamsters, etc.).

4.67 Ability to study the conditions of the experiment in order to detect any omissions, defects, or errors, particularly those errors which might have been introduced in the experimental results by coincidence or chance.

4.671 Given an experimental design the student will be able to identify and describe all those points in the procedure where human and non-human error could occur (e.g., chose reagent from wrong bottle, organisms not all same age, change in atmospheric pressure, voltage fluctuations in line, etc.).

4.7 Ability to accurately determine and record quantitative and qualitative data.

4.71 Ability to record the results, adhering strictly to standard definitions and usage of scientific terms.

4.711 Shown a film loop of the scale of some measuring device in which a change is taking place, the student will be able to accurately read the scale value every fifteen seconds for a period of three minutes and record the readings in the proper units on a prepared data table.

4.712 Shown a film loop of an activity which has a regular rhythm the student will be able to count the events and record them as the number of events per unit of time (e.g., fish gill openings per minute).

4.713 Shown a film loop of an activity in which it is necessary to record the events as a function of elapsed time the student will be able to do so (e.g., total growth over a period of time).

4.714 Shown a film loop of an activity in which there is no regularity the student will be able to count the number of events and record them as events per unit of time and also as events per elapsed time (e.g., Daphnia movements, etc.).

4.715 Given an experimental procedure the student will be able to correctly construct a table on which to record the data. The table will have correctly identified and allowed for the inclusion of all information required (e.g., units in which the readings are to be recorded, the heading for each column, allowance for the number of readings to be taken, the proper labeling of the tables, etc.).

4.72 Ability to solve the mathematical problems necessary in obtaining the pertinent data.

4.721 Ability to perform the fundamental operations of addition, subtraction, multiplication, and division.

4.7211 Given any set of positive and/or negative decimal or whole numbers the student will be able to add, subtract, multiply, or divide any set in any order with 100 per cent accuracy.

4.722 Ability to use essential formulas.

4.7221 Given a list of twenty-five numerical values the student will be able to calculate the mean given the proper formula.

4.7222 Given a list of twenty-five numerical values ranging from 1 to 25 the student will be able to calculate the sample variance given the proper formula.

4.7223 Given a list of 25 numerical values ranging from 1 to 75 the student will be able to calculate the standard deviation given the proper formula.

4.7224 Given a series of at least 10 values, the student will be able to calculate the standard error of the mean given the proper formula.

4.7225 Given two series of values of at least 10 values per series the student will be able to calculate a "student t" test value given the proper formula.

4.7226 Given two series of observed values of at least 10 values each and an expected percentage value for each series, the student will be able to calculate a Chi-Square value given the proper formula.

4.7227 Given any number the student will be able to write it in expotential form and given any number in expotential form the student will be able to convert it to ordinary decimal notation.

4.7228 Given any two numbers in expotential form the student will be able to add, subtract, multiply, or divide them.

4.7229 Given any decimal or whole number the student will be able to determine its common logarithm, and given any logarithm value the student will be able to find its antilogarithm and demonstrate addition, subtraction, multiplication, and division of common logarithms.

4.8 Ability to organize and display data.

4.81 Ability to construct graphs.

4.811 Given data in table form the student will be able to construct a point graph in a fashion acceptable by the <u>AIBS Style Manual</u>.

4.812 Given data in table form the student will be able to construct a bar graph in a fashion acceptable by the <u>AIBS Style Manual</u>.

4.813 Given data in table form the student will be able to construct a histogram in a fashion acceptable by the <u>AIBS Style Manual</u>.

4.814 Given data in tabular form the student will be able to order the data into groups or ranges of a property which are of equal size intervals.

4.815 Given a graph of some data the student will be able to construct a table of the data.

4.816 Given a set of measurements of a quantity or object the student will be able to construct a bar graph of the frequency distribution of the measurements.

4.82 Ability to construct diagrams.

4.821 Given a common three dimensional object the student will be able to construct a drawing of the shape.

4.822 Given an experimental procedure the student will be able to diagram the sequence of events to be followed in the procedure.

4.823 Given a photograph of an object the student will be able to draw a reasonable facsimile of it.

4.824 Given an object which changes over time the student will be able to draw at least four different stages of the event (e.g., growth of a plant, turbidity of a culture, layering of sediment).

4.825 Given an organism or part of an organism which must be viewed at least through a stereoscope the student will be able to draw the object in detail (e.g., Daphnia, butterfly wing, surgically removed rat ovary, etc.).

4.82 Ability to prepare summaries.

4.831 Shown a film loop of the operation of a research procedure and a table of the data obtained from the work the student will be able to write an accurate 30-50 word summary of the work and the results.

4.832 Given three different graphs of three different procedures on the same type of organism (e.g., respiration rate of an invertebrate with light constant and temperature increasing, temperature constant and light increasing, light and temperature constant and salinity increasing), the student will be able to write an accurate 20-30 word summary of each graph and an accurate 75-100 word summary of all three graphs.

4.9 Ability to interpret data.

4.91 Ability to recognize hypotheses and conclusions which are contradicted by the data.

4.911 Given a hypothesis and the related experimental data the student will be able to evaluate the hypothesis as accepted or rejected based on the data.

4.92 Ability to select the hypothesis from a group of hypotheses which most adequately explains the data.

4.921 Given a number of observations, tables of paired events and graphs of paired events about a process, the student will be able to choose the hypothesis out of a series of hypotheses which best explains the data.

4.922 Given a number of observations, tables of paired events, and graphs of paired events about a process, the student will be able to construct one or more models of the process.

4.923 Given a hypothesis and observations from the test of the hypothesis the student will be able to modify the hypothesis so that it is more in accord with the data.

4.924 Given a null hypothesis and a table of data of a test of the hypothesis the student will be able to choose a level of significance and evaluate the acceptance or rejection of the hypothesis based on his own calculations of the "student t" test.

4.925 Given a null hypothesis and a table of data of a test of the hypothesis the student will be able to set a level of significance and evaluate the acceptance or rejection of the hypothesis based on his own calculations of the Chi-Square test.

4.926 Given a table or graph of paired events the student will be able to construct a 20-30 word statement of information communicated about the response of one variable to the manipulated variable.

5.0 Ability to draw conclusions.

5.1 Ability to arrive at a solution to a problem based on an honest, unbiased appraisal of the data.

5.11 Using data and interpretations of the data generated by himself the student will be able to state a conclusion which strictly adheres to the experimental data.

5.2 Ability to suspend judgments when the results are inconclusive.

5.21 Given a hypothesis and data which do not affirm or refute the hypothesis, the student will be able to state that the results are inconclusive.

5.3 Ability to make inferences based on the conclusion when facing new situations in which the same factors are operating.

5.31 Given a hypothesis and data from a test of the hypothesis the student will be able to arrive at a conclusion consistent with the data and he will be able to make inferences as to other situations in which the same hypothesis and conclusion will hold.

6.0 Ability to communicate.

6.1 The student will be able to name the parts of a report or an experiment or other test and identify those statements which should be included in each part of the report.

6.2 The student will be able to construct a report which is neat, grammatically correct 95 per cent of the time, and correct as to content and style. The report will consist of a question to be answered, the statement of a testable hypothesis, a description of a test that will provide data to answer the question, identification of all variables to be controlled, all definitions operationally defined, all procedures described, the data collected and interpreted, and a conclusion stated.

APPENDIX C

ENCLOSURE LETTER AND QUESTIONNAIRE

O K L A H O M A   S T A T E   U N I V E R S I T Y · S T I L L W A T E R

Research Foundation 74074
(405) 372-6211, Ext. 271

Dear Colleague:

Gregor Ramsey and Robert Howe have stated:

> It has become almost self evident that one of the aims of science teaching is to develop problem solving skills and that the laboratory is the place where the student may be introduced to the experimental method for solving problems. Yet very few studies in the literature attempt to analyze the processes of problem solving. . . . It has been suggested, and indeed it is the trend in many of the course improvement projects, to make the laboratory experiences central to instructional procedures in science. Yet direct research on what these experiences should be, how they should be organized, and where they function best, is indeed meager. . . . Laboratory experiences should be designed as problem solving experiences, and should be directed to specified learning outcomes. More research is needed on how students solve problems both individually and in groups so that more efficient instructional procedures can be designed.

Instructors, like yourself, who have the day to day, year by year, responsibility for planning, organizing, operating, and evaluating the non-major general biology course are the only ones who can and should identify the important outcomes of the course. Because of your unique position we need your help in assessing the current thinking in the field of non-major general biology laboratory learning outcomes.

In an attempt to determine the present status of thinking on this matter, questionnaires are being sent to each instructor in the state of Missouri who has the responsibility for planning, organizing, operating and evaluating the non-major general biology course. You will be making a positive contribution to the teaching profession by filling out and returning the attached questionnaire. Individual institutions or instructors will not be identified in any way. Please return the questionnaire during the week of Oct. 18 to Oct. 22, 1971.

Sincerely,

/s/ Kenneth E. Wiggins

Dr. Kenneth Wiggins
Associate Director
Research Foundation
Chairman, Doctoral Committee

/s/ Gary D. Jensen

Gary D. Jensen
Doctoral Candidate
Oklahoma State University
Stillwater, Oklahoma 74074

Enclosures

BEHAVIORAL OBJECTIVES FOR THE LABORATORY OF A NON-MAJOR COURSE IN GENERAL BIOLOGY

Questionnaire

Personal Data Sheet

1. The institution at which you now teach is a(n): University_____, State College_____, Private Liberal Arts College_____, Junior College_____.
2. Your sex is: Female_____, Male_____.
3. Your age is: 25-30_____, 31-36_____, 37-43_____, 44-48_____, 49-53_____, 54-65_____.
4. You have had 0_____, 1-3_____, 4-6_____, years of previous teaching experience at the high school level.
5. You consider your own professional worth to be mainly in research_____ or teaching_____.
6. The highest earned degree now held by you is: Ph.D._____, Ed.D._____, M.A. + 30_____, M.A. + 15_____, M.A._____, B.A. + 30_____, B.A. + 15_____, B.A._____.
7. You received your Bachelor's degree from a(n): University_____, State College_____, Private Liberal Arts College_____.
8. Including this present year, how many years have you taught or participated in the non-major general biology course? 1-3___, 4-6__, 7-10_____, 11-14_____, 15-17_____, 18-20_____, 20 + _____.
9. Your present involvement in teaching the non-major general biology course was chosen_____ by you or was assigned_____ to you.
10. To the best of your knowledge, there are_____ or are not_____ declared majors enrolled in the non-major biology course.

11. In the practice of teaching the non-major biology course, do you purposely try_____ or do not try_____ to recruit non-majors to become majors?
12. In any one academic year there are between 1-100_____, 101-250___, 251-500_____, 501-700_____, 751-1000+_____, students enrolled in the non-major general biology course.
13. Does the department with which you are now associated offer one or more Master's degree programs? Yes_____, No_____.
Doctor's? Yes_____, No_____.
14. Do you at the present have any involvement in the teaching of a graduate level course? Yes_____, No_____.
15. How many semester hours of credit in courses related to the history, philosophy, methods, and psychology of education and teaching do you have? 0_____, 3-6_____, 7-12_____, 13-18_____, 19-24_____.
16. Including this present year how many years of teaching at the collegiate level have you had? 1-3_____, 4-6_____, 7-10_____, 11-14_____, 15-17_____, 17-20_____, 20+_____.
17. In your latest degree program, did you participate as a teaching assistant? Yes_____, No_____.
18. Have you attended one or more NSF institutes for high school or college teachers? Yes_____, No_____.
19. You took your introductory general biology course in a(n): University_____, State College_____, Private Liberal Arts College _____, Junior College_____.
20. Your present rank is: Full Professor_____, Associate Professor _____, Assistant Professor_____, Instructor_____, Graduate Assistant_____.
21. You are now employed on a full time_____ or part time_____ basis.
22. You are presently concerned in some capacity with the planning, organization, operation, or evaluating of the non-major general biology course. Yes_____, No_____.

This questionnaire has been constructed so as to take a minimum amount of your time. You are asked to indicate on the five-point scale found at the end of each statement the degree to which you feel the statement is an important learning outcome for the laboratory of a non-major college level course in general biology. To register a very strong favorable opinion you should circle the number five (5) on the scale. To register a very weak or unfavorable opinion you should circle the number one (1) of the scale. To register an opinion between these two extremes you should circle either (4), (3), or (2), with the number three (3) being a generally neutral point.

EXAMPLE

42. The student will be able to use any piece of volumetric glassware with no more than ± 1% error 5 (4) 3 2 1

This circle indicates that you consider this behavioral objective to be of relatively great importance as a learning outcome of the laboratory in a non-major general biology course.

1.1 ABILITY TO FORMULATE SIGNIFICANT PROBLEMS

1. The student, when directed to do so, will be able to describe in written form at least three problems, within a week's period, which are of importance to him. The statement will consist of a concise description of the situation, the probable contributing factors, and a possible method of solution . . 5 4 3 2 1

2. Given a paragraph or an article of a descriptive nature as found in the popular literature (e.g. Ardery, Robert, "Is Man Naturally Violent?" Readers Digest, Dec. 1971, 115-119), the student will be able to identify in written form from one to three significant problems found in the material. The statements will consist of a concise description of the situation, the probable contributing factors, and a possible method of investigation 5 4 3 2 1

3. Given a living population (balanced aquarium, earthworms, spiders, cockroaches, white mice, ants, meal worms, Daphnia, Drosphila, etc.), and directed to identify at least ten problems, questions, or observations raised by observing the population daily for one month, the student will be able to do so 5 4 3 2 1

1.2 ABILITY TO ANALYZE PROBLEMS

4. Given a written description of a complex problem made up of at least three separate problems (e.g. stream fish kill: local economics, local agricultural activities, local industry, local sewage

treatment), the student will be able to isolate and identify the separate problems 5 4 3 2 1

5. Given a description of a situation (e.g. when the aerator stops working the snails begin to migrate towards the upper part of the aquarium), the student will be able to identify at least three possible causative factors and to choose the most probable. 5 4 3 2 1

6. Given quantitative data summarized in tables and graphs the student will be able to construct one or more inferences consistent with the data . . . 5 4 3 2 1

7. The student will be able to identify and name properties of an object or situation by using at least four of his senses 5 4 3 2 1

8. Given an operational definition the student will be able to distinguish or identify an object or event from among a group of similar objects or events 5 4 3 2 1

9. The student will be able to construct an operational definition of an object from a multistage classification of a set of objects which includes the object to be defined 5 4 3 2 1

10. The student will be able to construct an operational definition which adequately describes a procedure, object or property of an object in the context in which it is used 5 4 3 2 1

11. Given a hypothesis, inference, question, graph, or table of data, the student will be able to identify variables or words for which an operational definition is needed 5 4 3 2 1

12. Given a description of a situation the student will be able to construct a concise question which will isolate a possible causative factor and make it researchable 5 4 3 2 1

1.3 ABILITY TO OBTAIN INFORMATION REGARDING A PROBLEM STATEMENT FROM A VARIETY OF SOURCES

13. Given a problem statement the student will be able to pick out the key words and locate materials in any one of the following: Biological Abstracts, The Handbook of Biological Data, annual index of Science, annual index of Scientific American . . . 5 4 3 2 1

14. Given a problem statement the student will be able to locate related materials by using the <u>Readers Guide to Periodical Literature</u> 5 4 3 2 1

15. Given a properly labeled graph the student will be able to describe the probable experimental procedure used to gain the information 5 4 3 2 1

16. Given a bibliographic citation of a journal article the student will be able to identify the author, journal title, article title, the year and month published, and the page on which the article begins and ends 5 4 3 2 1

17. Given three articles with closely related content, each no less than five pages long, the student will be able to develop a single outline which will contain the major topics and subtopics of all three articles 5 4 3 2 1

18. Given a problem statement and a series of 35mm slides, or a series of photographs, or a motion picture related to the problem, the student will be able to write a 40-60 word description of the relationships between the visual and the problem statement 5 4 3 2 1

19. Given a problem statement and a model or exhibit related to the problem, the student will be able to write a 40-60 word description of the relationship between the visual and the problem statement 5 4 3 2 1

20. Given a problem statement and a journal article of not more than five pages the student will within five minutes be able to skim the material and evaluate its relevance to the problem statement . 5 4 3 2 1

21. Given a problem statement and a situation or condition in the local community relevant to the problem the student will be able to write a 40-60 word description illustrating the relationship of his observations to the problem statement 5 4 3 2 1

22. Given a problem statement the student will be able to develop an index card file of no less than twenty different entries related to the problem statement. Each entry will have complete bibliographic information and an abstract of no less than 100 words 5 4 3 2 1

23. Given a problem statement and a list of journals the student will be able to correctly rank these journals from most to least reliable as sources of information in the solution of the problem . . 5 4 3 2 1

1.4 **ABILITY TO DEVISE EXPERIMENTS SUITABLE TO THE SOLUTION OF A PROBLEM**

24. Given a problem statement and a series of hypotheses the student will be able to correctly rank the hypotheses from most reasonable to least reasonable 5 4 3 2 1

25. Given a factor in an experiment the student will be able to suggest means for holding that factor constant 5 4 3 2 1

26. Given a description of the relationship between two variables the student will be able to construct a generalized graph and name the dependent and independent variable 5 4 3 2 1

27. Given a properly drawn and labeled graph of the relationship between two variables the student will be able to predict the effect of altering an experimental condition, identify and name the variables that should be held constant, the one that should be manipulated, and the one that should be allowed to respond under the altered condition . . 5 4 3 2 1

28. Given an inference based on a set of observations or a prediction based on interpolation or extrapolation from a table of data, the student will be able to design an experiment which has an over-all control, a manipulated variable, and a responding variable 5 4 3 2 1

29. Given an inference and a test of that inference, or a prediction and a test of that prediction the student will be able to describe observations that would support or refute the inference or the prediction 5 4 3 2 1

30. Given an hypothesis and an experimental design to test it the student will be able to construct properly labeled tables for the collection of the data 5 4 3 2 1

31. Given a properly labeled data table and a list of test procedures the student will be able to identify those tests which will produce the type of data required 5 4 3 2 1

32. Given a problem statement, an hypothesis, and an experimental design, the student will be able to locate in the literature possible procedures for gathering data 5 4 3 2 1

1.5 ABILITY TO CRITICIZE FAULTY EXPERIMENTS

33. Given an experimental design in which the method of collecting the data was unreliable the student will be able to identify the fault and will be able to incorporate the needed changes 5 4 3 2 1

34. Given an experiment in which the data were not accurate the student will be able to identify the fault and suggest a remedy 5 4 3 2 1

35. Given an experiment in which the data were insufficient in number the student will be able to identify the shortcoming and suggest a remedy . . 5 4 3 2 1

36. Given an experimental design in which proper controls were not included the student will be able to identify the fault and incorporate the needed changes 5 4 3 2 1

37. Given an experimental design in which there were no controls included the student will be able to identify the fault and incorporate the needed changes 5 4 3 2 1

1.6 ABILITY TO CARRY OUT EXPERIMENTS

38. Given a properly written experimental procedure the student will be able to choose, set up, and operate all equipment needed 5 4 3 2 1

39. Given any one of the following pieces of equipment and the operating instructions the student will be able to demonstrate the proper technique for its use: Spectrophotometer 20, a student grade microscope with low, high and oil objectives, variable magnification stereoscope, two phase liquid chromatograph, electric balance, thermometer, magnetic stirrer, triple beam balance, dissecting set, bacterial colony counter, pH meter, bunsen burner, hot plate, table top centrifuge 5 4 3 2 1

40. Given any one of the following experimental organisms and adequate directions the student will demonstrate competence in the proper handling, housing, and feeding of them by maintaining a group for at least two months: hamsters, gerbils, at least four freshwater invertebrates, white mice, white rats, frogs, turtles, spiders, roaches, ants,

Drosophila, meal worms, bacteria, chicks, fish, plants 5 4 3 2 1

41. Shown a series of 35mm slides the student will be able to identify by name, describe the purpose of, and describe the general functioning of the following pieces of research equipment: electron microscope, oscilloscope, X-ray machine, computer, Warburg type respirometer, Physiograph, refrigerated centrifuge, gas chromatograph, infrared spectrometer, phase microscope, autoclave 5 4 3 2 1

42. The student will be able to use any piece of volumetric glassware with no more than 1% error . 5 4 3 2 1

43. Given any one of twenty common acids, bases, salts, or elements the student will be able to correctly make a solution of specified normality, molarity, molality, or percentage by weight or volume, in the volume required by an experimental procedure . 5 4 3 2 1

44. Given a dichotomous key and a set of objects the student will be able to identify any one of the objects 5 4 3 2 1

45. Given a series of quantitative values from a single event over time the student will be able to accurately describe the changes 5 4 3 2 1

46. Shown a film loop of a color change taking place in a test tube the student will be able to accurately describe the change 5 4 3 2 1

47. Given three different types of circumstances in each of the following categories of measurement: length, mass, time, volume, temperature, and quantity (e.g. length: plant height, cell width, distance traveled), the student will be able to take 10 different measurements in each of the circumstances and obtain results within 1% of the actual measurements 5 4 3 2 1

48. Given a properly written experimental procedure to be used on a specific experimental subject the student will be able to suggest how the same procedure could be used to accomplish the same thing in a different organism (e.g. auxin application to Coleus and to a liverwert, etc.) 5 4 3 2 1

49. Given a properly written experimental procedure to be used on a specific experimental subject the student will be able to identify those factors which will have to be accounted for in applying

the procedure to a different experimental subject (e.g., nutritional regime to white rats and hamsters, etc.) 5 4 3 2 1

50. Given an experimental design the students will be able to identify and describe all those points in the procedures where human and non-human error could occur (e.g. chose reagent from wrong bottle, organisms not all same age, change in atmospheric pressure, voltage fluctuations in line, etc.) . . 5 4 3 2 1

1.7 ABILITY TO ACCURATELY DETERMINE AND RECORD QUALITATIVE AND QUANTITATIVE DATA

51. Shown a film loop of the scale of some measuring device in which a change is taking place the student will be able to accurately read the scale value every fifteen seconds for a period of three minutes and record the readings in the proper units on a prepared data table 5 4 3 2 1

52. Shown a film loop of an activity which has a regular rhythm the student will be able to count the events and record them as the number of events per unit of time (e.g. fish gill openings per minute) 5 4 3 2 1

53. Shown a film loop of an activity in which it is necessary to record the events as a function of elapsed time the student will be able to do so (e.g. total growth over a period of time) 5 4 3 2 1

54. Shown a film loop of an activity in which there is no regularity the student will be able to count the number of events and record them as events per unit of time and also as events per elapsed time (e.g., Daphnia movements, etc.) 5 4 3 2 1

55. Given an experimental procedure the student will be able to correctly construct a table on which to record the data. The table will have correctly identified and allowed for the inclusion of all information required (e.g. units in which the readings are to be recorded, the heading for each column, allowance for the number of readings to be taken, the proper labeling of the tables, etc.) . 5 4 3 2 1

56. Given any set of positive and/or negative decimal or whole numbers the student will be able to add, subtract, multiply or divide any set in any order with 100% accuracy 5 4 3 2 1

57. Given a list of at least twenty-five numerical values ranging from 1 to 75 the student will be able, when given the proper formula, to calculate any of the following: mean, mode, median, sample variance, standard deviation, standard error of the mean 5 4 3 2 1

58. Given two series of values of at least 10 values per series the student will be able, when given the proper formula, to calculate either of the following: student "t" test, or a Chi-Square test 5 4 3 2 1

59. Given any number the student will be able to write it in expotential form and given any number in expotential form the student will be able to convert it to ordinary decimal notation 5 4 3 2 1

60. Given any two numbers in expotential form the student will be able to add, subtract, multiply or divide them 5 4 3 2 1

61. Given any decimal or whole number the student will be able to determine its common logarithm, and given any logarithm value the student will be able to find its antilogarithm and demonstrate addition, subtraction, multiplication, and division of common logarithms 5 4 3 2 1

1.8 ABILITY TO ORGANIZE AND DISPLAY DATA

62. Given data in table form the student will be able to construct any one of the following: point graph, bar graph, or histogram, in a fashion acceptable by the <u>AIBS Style Manual</u> 5 4 3 2 1

63. Given data in tabular form the student will be able to order the data into groups or ranges of a property which are of equal size intervals . . . 5 4 3 2 1

64. Given a graph of some data the student will be able to construct a table of the data 5 4 3 2 1

65. Given a common three dimensional object the student will be able to construct a drawing of the shape 5 4 3 2 1

66. Given an experimental procedure the student will be able to diagram the sequence of events to be followed in the procedure 5 4 3 2 1

67. Given an object or event which changes over time the student will be able to draw at least four different stages of the event (e.g. growth of a plant, turbidity of a culture, layering of sediment) . . 5 4 3 2 1

68. Given an organism or part of an organism which must be viewed at least through a stereoscope the student will be able to draw the object in detail (e.g. Daphnia, butterfly wing, surgically removed rat ovary, etc.) 5 4 3 2 1

69. Shown a film loop of the operation of a research procedure and a table of the data obtained from the work the student will be able to write an accurate 30-50 word summary of the work and the results 5 4 3 2 1

70. Given three different graphs of three different procedures on the same type of organism (e.g. respiration rate of an invertebrate with light constant and temperature increasing, temperature constant and light increasing, light and temperature constant and salinity increasing) the student will be able to write an accurate 20-30 word summary of each graph and an accurate 75-100 word summary of all three graphs 5 4 3 2 1

1.9 ABILITY TO INTERPRET DATA

71. Given an hypothesis, a table of data, and a conclusion supporting the hypothesis the student will be able to evaluate the conclusion as correct or incorrect on the basis of the data 5 4 3 2 1

72. Given a number of observations, tables of paired events, and graphs of paired events about a process, the student will be able to choose the hypothesis out of a series of hypotheses which best explains the data 5 4 3 2 1

73. Given a number of observations, tables of paired events, and graphs of paired events about a process, the student will be able to construct one or more models of the process 5 4 3 2 1

74. Given a null hypothesis and a table of data of a test of the hypothesis the student will be able to choose a level of significance and evaluate the acceptance or rejection of the hypothesis based on his own calculations of the student "t" test of the Chi-Square test 5 4 3 2 1

75. Given a graph the student will be able to identify the relationship between the dependent and independent variable as either linear or nonlinear and will be able to describe the information provided by the graph 5 4 3 2 1

76. Given a table or graph of paired events the student will be able to construct a 20-30 word statement of information communicated about the response of one variable to the manipulated variable . . . 5 4 3 2 1

77. Given a written report of a research project the student will be able to write an abstract of the article 5 4 3 2 1

78. Given a table of paired events the student will be able to identify the dependent (responding) variables and the independent (manipulated) variable . 5 4 3 2 1

79. Given a properly drawn and labeled graph on semi-log graph paper the student will be able to identify the independent and dependent variable and construct a 20-30 word description of the information contained in the graph 5 4 3 2 1

80. Given a properly drawn and labeled graph the student will be able to make predictions by extrapolating beyond the range of observed events or to make predictions, by interpolating between the observed events 5 4 3 2 1

2.0 ABILITY TO DRAW CONCLUSIONS

81. Using data and interpretations of the data generated by himself the student will be able to state a conclusion which strictly adheres to the experimental data 5 4 3 2 1

82. Given a hypothesis and data which do not affirm or refute the hypothesis the student will be able to state that the results are inconclusive . 5 4 3 2 1

83. Given a hypothesis and data from a test of the hypothesis the student will be able to arrive at a conclusion consistent with the data and he will be able to make inferences as to other situations in which the same hypothesis and conclusions will hold 5 4 3 2 1

2.1 ABILITY TO COMMUNICATE

84. The student will be able to name the parts of a report of an experiment or other test and identify those statements which should be included in each part of the report 5 4 3 2 1

85. The student will be able to construct a report which is neat, grammatically correct 95% of the time, and correct as to content and style. The report will consist of a question to be answered, the statement of a testable hypothesis, a description of a test that will provide data to answer the question, identification of all variables to be controlled, all definitions operationally defined, all procedures described, the data collected and interpreted and a conclusion stated 5 4 3 2 1

If you would like a summary of the results of this work,

check here ______________

Thank you. I appreciate your cooperation and effort on this work.

VITA

Gary Dean Jensen

Candidate for the Degree of

Doctor of Education

Thesis: THE DEVELOPMENT AND EVALUATION OF SOME BEHAVIORAL OBJECTIVES FOR THE LABORATORY OF A NON-MAJOR COLLEGE LEVEL COURSE IN GENERAL BIOLOGY

Major Field: Higher Education

Biographical:

Personal Data: Born at Grand Island, Nebraska, January 12, 1937, the son of Oscar F. and Helen M. Jensen.

Education: Attended grade school at Grand Island, Nebraska; graduated from Grand Island Senior High in 1955; received the Bachelor of Science degree from the University of Nebraska, with a major in Zoology, in August, 1962; received the Master of Arts degree from the State College of Iowa with a major in Biology in May of 1966; completed requirements for the Doctor of Education degree in May, 1972.

Professional Experience: Teaching experience includes three years as a biology teacher at Niobrara County High School in Lusk, Wyoming; four years as Assistant Professor of Biology at Tarkio College, Tarkio, Missouri; Presently on leave of absence from Tarkio College.