Current practices in the teaching of college general chemistry laboratory in the Northwestern states to 1958
by George Herman Gloege

A DISSERTATION Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Doctor of Education
Montana State University

Abstract:
An investigation of the current practices in the teaching of college general chemistry laboratory in the Northwestern States to 1958 was made by means of a careful review of the literature and by an analysis of the results of a questionnaire.

The literature review indicated the importance of laboratory work and revealed the laboratory as one of the best places to bring about the realization of the objectives in teaching of college general chemistry.

The analysis of the results of the questionnaire indicated: 1. That the objectives of teaching college general chemistry were well recognized.

2. That there were in process few important innovations in current teaching practices.

3. That some of the laboratory practices were designed for the benefit of the students, as the pre-explanation of the experiments and the favorable physical situation in the laboratory.

4. That some of the highly recommended teaching practices as emphasized in the literature were being used, such as the use of unknowns and the quantitative approach, and provision for individual work.

5. That the demonstration was not taking the place of individual laboratory work, but was being used largely when difficult or dangerous experiments were necessary.

6. That some of the practices being used in the laboratory were not of the recommended types, as (a) the all too frequent use of recipe-like directions given in the laboratory manuals with preparation of reports by the filling in of blanks; (b) the lack of a consistent pattern of laboratory supervision; (c) the use of the tight planned schedule which discourages independent study; (d) the lack of opportunities for students to work as the scientist works in the solution of problems; (e) and the lack of a system of laboratory evaluation which measures some of the competencies peculiar to laboratory work.

It is recommended that attention be given to the development of some better types of laboratory manuals, that more attention be given to the objectives which include problem-solving skills, and scientific attitudes and appreciations, and that some new instruments for laboratory evaluation be devised.

CURRENT PRACTICES IN THE TEACHING OF COLLEGE GENERAL CHEMISTRY LABORATORY IN THE NORTHWESTERN STATES TO 1958

by

George H. Gloege

A DISSERTATION

Submitted to the Graduate Faculty

in

partial fulfillment of the requirements

for the degree of

Doctor of Education

at

Montana State College

Approved:

____
Head, Major Department

____
Chairman, Examining Committee

____
Dean, Graduate Division

Bozeman, Montana

June, 1960

TO

My wife, Bernice, an ever

positive catalyst

G. H. G.

TABLE OF CONTENTS

LIST OF TABLES

TABLE		PAGE

ABSTRACT

An investigation of the current practices in the teaching of college general chemistry laboratory in the Northwestern States to 1958 was made by means of a careful review of the literature and by an analysis of the results of a questionnaire.

The literature review indicated the importance of laboratory work and revealed the laboratory as one of the best places to bring about the realization of the objectives in teaching of college general chemistry.

The analysis of the results of the questionnaire indicated:

1. That the objectives of teaching college general chemistry were well recognized.

2. That there were in process few important innovations in current teaching practices.

3. That some of the laboratory practices were designed for the benefit of the students, as the pre-explanation of the experiments and the favorable physical situation in the laboratory.

4. That some of the highly recommended teaching practices as emphasized in the literature were being used, such as the use of unknowns and the quantitative approach, and provision for individual work.

5. That the demonstration was not taking the place of individual laboratory work, but was being used largely when difficult or dangerous experiments were necessary.

6. That some of the practices being used in the laboratory were not of the recommended types, as (a) the all too frequent use of recipe-like directions given in the laboratory manuals with preparation of reports by the filling in of blanks; (b) the lack of a consistent pattern of laboratory supervision; (c) the use of the tight planned schedule which discourages independent study; (d) the lack of opportunities for students to work as the scientist works in the solution of problems; (e) and the lack of a system of laboratory evaluation which measures some of the competencies peculiar to laboratory work.

It is recommended that attention be given to the development of some better types of laboratory manuals, that more attention be given to the objectives which include problem-solving skills, and scientific attitudes and appreciations, and that some new instruments for laboratory evaluation be devised.

CHAPTER I

INTRODUCTION

This investigation, "Current Practices in the Teaching of College General Chemistry Laboratory," developed not only from the author's experiences as a teacher of college general chemistry, but also from the fact that for a long time laboratory work has been accepted as a part of the teaching of college general chemistry. It is a matter of historical record, according to Blick,[1] that laboratory teaching began in Europe in the early years of the seventeenth century. In the United States laboratory work has been a commonly used procedure for fifty years or more. In the earlier years of instruction in chemistry, the laboratory was a place where students could come to work on their chemistry problems.[2] The laboratory gradually became a place where students came in contact with the materials being studied; developed manipulative skills, self-reliance, accuracy, ability to interpret data, curiosity, and scientific attitudes; and became familiar with the scientific method.[1] Teacher training courses in the United States emphasized these values of the laboratory as a part of the required learning in science courses.

These essential values of laboratory training were supported by

---

[1]Numbers in superscripts refer to numbered references in the bibliography, see Appendix G.

certain principles of the psychology of learning. Hill[3] reviewed some of these principles with his statement that "one only learns what he does, thinks and feels." He further stated that "...there is no significant learning without problem-solving," and that problems come from needs or gaps in experience. The laboratory, by name and by custom, was set up as a place to work and to do things. The most rewarding kind of doing was that kind which came when students worked on solutions to problems, especially their own problems. Horton[4] stated it this way, "...the best results point to individually directed experimentation in problematic situations."

However, greater student enrollments, with attendant reduction of per capita space and increase in student-teacher ratio increased interest in the demonstration as a substitute for a part or all of the individual laboratory work. Savings in time, space and personnel were claimed by the users of the demonstration.[5,6,7,8] Students, on the basis of tests administered, appeared to be doing as well as, or better than, when taught by the individual laboratory method.[9,10,11,12] Analysis of the testing instruments indicated that it was principally a knowledge of factual information that was being measured.[10] It was stated above that laboratory work has other objectives than the learning of factual information. Therefore, either the measuring instruments were not properly measuring laboratory work or something was happening to the quality of laboratory instruction.

There began in the 1930's[13] and continued into the 1950's[14,15,16,17,18,19,20] a growing concern with what appeared to be ineffectual methods of laboratory teaching, particularly as that teaching was hampered by the use of available laboratory manuals. Some of these manuals made use of recipe-like directions for the experiments with blanks to be filled in with predetermined answers which might easily have been copied from another student's notebook or from the textbook.[18,19,20,21,23]

Studies of some of the ineffectual methods of laboratory teaching that have been recorded in the literature included such criticisms as: few laboratory experiments were scientific;[13] many of the experiments were of an incorrect type;[24,25] supervision was lax;[26] too much was being done for the student who did too little for himself;[19,27] and evaluation procedures were not measuring the kind of activities which were done in the laboratory.[28,29]

An association with other teachers of chemistry at the Third Chemistry Institute held at Montana State College in 1956 reemphasized the importance of laboratory work, and brought forth further evidence of some of the ineffective methods of laboratory teaching.

A desire to study the actual laboratory practices in the teaching of college general chemistry came from the belief that (1) laboratory teaching in chemistry is a practice of long standing, (2) good laboratory teaching has made an important contribution to education in chemistry, (3) good learning principles support teaching by the laboratory method, (4) teaching by use of laboratory work has been questioned by certain supporters of the demonstration method of teaching, and (5) ineffective methods of laboratory teaching can hamper the laboratory teaching procedure.

The need for carrying out a study of the actual practices in the teaching of college general chemistry laboratory seemed vital: (1) in determining the true objectives of laboratory experience as a teaching device, (2) in ascertaining whether or not other teachers were experiencing some misgivings about the effectiveness of laboratory teaching and (3) in finding out the actual practices being used in the teaching of college general chemistry laboratory.

Statement of the Problem

The situation presented in this investigation evolved from the need of discovering the "Current Practices in the Teaching of College General Chemistry Laboratory." In order to discover such practices, answers to a number of questions prepared from a survey of the literature needed to be determined. These questions, when documented and validated, appeared in the form of a questionnaire, a copy of which has been placed in Appendix A. This questionnaire was used to furnish the desired data.

Procedures

The "current practices in the teaching of college general chemistry laboratory" were determined by making use of the following procedures:

1. An examination of the literature to (a) make a survey of current teaching practices, (b) prepare an annotated bibliography of same and (c) secure items for the questionnaire.

2. Preparation and administration of a questionnaire.

3. Treatment of the questionnaire and analysis of the results to (a) determine the objectives of such teaching, (b) determine the actual teaching practices and (c) discover the awareness of the instructors of the ineffectiveness of certain teaching practices.

4. Presentation of the results and especially of recommendations of some of the better laboratory teaching practices.

Limitations

The sampling, to be characteristic of the general population of those practicing the teaching of college general chemistry laboratory, had to be representative of the whole of such population. In this instance all of the four-year accredited colleges and universities in the four-state region of Idaho, Montana, Oregon and Washington which offered a course in college general chemistry were sampled. These institutions ranged in size from the small college with one chemistry instructor to the larger university with many. The inclusion of all the colleges and universities in this region which were accredited for four years and which offered the college general chemistry course assured a representative and random sampling that could be extended to a larger region including more such institutions.

CHAPTER II

REVIEW OF THE LITERATURE

The first step in this study, as was indicated in Chapter I, was to review the literature relating to the practices of teaching college general chemistry laboratory. The purpose of this examination of the literature was to make a survey of teaching practices, prepare an annotated bibliography, and secure items for inclusion in a questionnaire.

Methods of Laboratory Teaching

The laboratory manuals have been the subject of much discussion and thus presented a convenient starting point for the literature review. Garad[13] found that only three of 28 laboratory manuals examined indicated the use of the scientific method. Lewis[14] found 61 different manuals in use in 94 colleges surveyed, with only nine colleges using the same manual. The percentage of use of the individual experiments varied from one to 86 percent, and no one particular experiment was used by all the colleges.

Several writers[15,16] have advocated the complete elimination of the laboratory manual and the substitution of student planned laboratory experiments. Another[5] suggested the use of the laboratory quiz as a substitute for the usual laboratory report.

Three terms were found to be commonly used in describing the manner in which students do their laboratory work: "cook-booking," "dry-labbing," and "blank-filling." "Cook-booking" was defined[6] as the following of directions blindly or the giving of unreasoning obedience to printed statements. "Dry-labbing" was defined as the copying of answers into the laboratory reports from some source other than the experiment such as another student's paper, a textbook or reference book. "Blank-filling"[8] was described as the process of filling in of the blanks which are commonly found in the laboratory manuals.

Alyea[19] advocated the laboratory as a means of teaching but without "cook-booking." Hopkins[20] described two types of manuals: the "plain" type and the "fill-in" type; the latter, according to him, led to superficial work.

It was evident from the literature that the laboratory manuals and their use were under criticism for: (1) lack of use of the scientific method, (2) too much "cook-booking," (3) doing too much for the student and leaving too little for the student to do for himself, (4) too much opportunity for "blank-filling," and "dry-labbing," (5) too little use of the many manuals which are published.

Several authors indicated the need for improved practices for doing laboratory work. Some of these that were mentioned in the literature included:

1. The use of simple, student-devised experiments.[19]

2. The use of the "open-end"*type of experiment.[33]

3. The use of more qualitative and quantitative analysis experiments.[1,34]

4. The provision for more opportunities for students to help in planning experiments.[27]

5. The return to the formal or essay type of laboratory report.[22]

6. The evaluation of laboratory experiments by quizzing rather than by reports.[32]

7. The use of the laboratory only when problems can best be solved by laboratory work.[24,35]

8. The provision for closer supervision of students.[36]

9. The use of more of the "junior" research type of experiment.[37,38]

10. The use of more real experimentation.[24,25]

11. The possible use of a new type of laboratory manual like that published by Young[39] which provides for the selection and solution of problems by students, with no blanks to be filled or recipes to be followed.

It was apparent that a growing concern did exist with some of the

---

*Symbols are used to indicate footnotes, since numbers refer to the bibliography. A brief description of the "open-end" type of experiment has been prepared and placed in Appendix B.

apparently ineffectual methods of laboratory teaching particularly as applied to the laboratory manual and its use, the method used by students in preparing and reporting laboratory experiments, the type of experiments in use, and the use being made of the laboratory. An investigation of the objectives of laboratory teaching to bring into focus the reasons for using the laboratory as a means of teaching of chemistry was next undertaken.

Objectives of Laboratory Teaching

The objectives or goals of teaching college general chemistry laboratory were next to be reviewed because they serve to give direction and purpose to teaching methods. A real stimulus to a review of the objectives of science teaching came in 1932 with the publication of A Program for Teaching Science,[40] the Thirty-first Yearbook, Part I, of the National Society for the Study of Education. In this publication, attention was directed to the objectives of, and to the needed changes in the practices of science teaching in the schools from the primary grades through junior college.

A Program for Teaching Science was an opening wedge in the movement for the improvement of science teaching, but a more comprehensive study appeared in 1947, Science Education in American Schools, the

Forty-sixth Yearbook of the same organization. This latter publication presented a statement of objectives under eight general headings:

1. Functional information or facts
2. Functional concepts
3. Functional understanding of principles
4. Instrumental skills
5. Problem-solving skills
6. Attitudes
7. Appreciations
8. Interests

Each of these objectives was illustrated, analyzed and related to the objectives of general education.

A general discussion of the objectives or goals of teaching college general chemistry included the following:

Functional Information or Facts. The knowledge of facts, principles, laws and theories is of importance for several reasons:

1. As preparation for advanced study in science[47]
2. As a means of giving information about and skill in science[42]
3. As a basis for the understanding of scientific thinking[42]
4. As one of the aspects of a liberal arts, a professional, a specialized education or of a technical training[1]

Functional Concepts. Functional concepts were defined, accordind to the Forty-sixth Yearbook,[41] as "syntheses or constellations of meanings varying all the way from the simple to the complex." However, it was very difficult to find complete elucidation in the literature of the word concept and its value or meaning in the teaching of science. The lack of specific definition of this word was possibly due to a confusion of its meaning with the meaning of the word principle.

Functional Principles. The confusion in the meaning of the two terms, concepts and principles, created a need for a definition of the latter. According to the Forty-sixth Yearbook[41] "a scientific principle must:

1. Be a statement of some fundamental process or constant mode of behavior.

2. Be true without exception within the limitations stated.

3. Be capable of demonstration or illustration.

4. Not be a part of a larger principle..

5. Not be a definition.

6. Not deal with specific substances or varieties or within limited groups of substances or varieties."

The Yearbook indicated further that even though facts, concepts and principles overlapped, a knowledge of facts served not as an end but as a means to the gaining of understanding of concepts and principles.

Functional principles were found to be important objectives of science teaching and especially of laboratory teaching: (1) in their application to solving daily problems in new situations,[47] (2) in providing for opportunities for their use and application in laboratory manipulations,[43] (3) in providing opportunity for their first hand observation.[44] In short, the laboratory was defined as a place where the principles of chemistry are brought to life for the students; a place where principles may be tested, and, perhaps, where their application may help in solving some problems of daily living.

Instrumental Skills. The instrumental skills include not only the ability to handle laboratory apparatus and scientific instruments, but the ability to read and to manipulate the mathematics required for scientific tasks. The instrumental skills provide the means for the attainment of other objectives.

Adams[49] found that the use of instruments in the laboratory was an objective which had the approval of 66 percent of the colleges surveyed in 34 states.

The development of instrumental skills is an important objective of laboratory teaching. The application of facts and principles comes through experimentation,[44] new facts and principles are derived from experimentation,[48] and instrumental skills are necessary for experimentation.

Hildebrand[140] stated that the authority for the experiment is the test tube rather than the textbook or the teacher, and thus emphasized the value of instrumental skills.

Blick[1] went so far as to indicate that college general chemistry should include the skills that will help in professional, specialized, and technical training in chemistry.

Problem-Solving Skills. The four terms, problem-solving, scientific method, reflective thinking and scientific thinking, as used in the literature, are somewhat confusing and are used synonymously.

The use of the scientific method as an objective for the teaching of college general chemistry figured prominently in lists compiled by Smith,[42] Bucham,[51] Smith,[47] Swinnerton,[160] and Kirk.[52] Bergen[50] found, from a study of 57 objectives of the teaching of science, that most observers favored scientific thinking over specific knowledge.

Attitudes, Appreciations and Interests. Attitudes, appreciations and interests are not to be considered as intangibles, according to the Forty-sixth Yearbook,[41] when making an inventory of objectives for laboratory teaching. Some examples of attitudes, appreciations and interests expressed as objectives for the teaching of laboratory work are:

1. Appreciation by students of training in the scientific method and in chemical knowledge.[47]

2. Understanding and appreciation of the significance of chemistry in our modern civilization.[48]

3. Inspiring of students with confidence in the scientist.[48]

4. Getting into the spirit of chemistry and getting the spirit of discovery.[53]

5. Appreciation and understanding of the universe.[43]

6. Determination of interests and aptitudes in chemistry as a vocation.[53]

7. Appreciation of our environment and the impact of scientific thinking upon our civilization.[49]

8. Satisfaction of curiosity.[46,49]

Summary of the Objectives of Laboratory Teaching. This review of the literature of the objectives of laboratory teaching brought into focus several important teaching concepts:

1. Facts are important, but not necessarily in themselves; they point the way to understanding, thinking and advanced study in science.

2. Concepts and principles are the "big ideas" which make chemistry come to life.

3. Instrumental skills are a very important part of laboratory teaching.

4. Problem-solving skills are basic to science, and there is, perhaps, no better place to develop them than through the proper kind of laboratory work.

5. Attitudes, appreciations and interests are extremely important and lead to good end results.

The volume of the literature devoted to the objectives of science teaching, the renewed emphasis upon these objectives, the publication of the two important yearbooks, indicate directly and by implication that all is not well in the teaching of laboratory work.

Problem-Solving

Problem-solving was discussed briefly in the previous section on the objectives of laboratory teaching. The purpose of this section is to explore problem-solving as a teaching device. A convenient point of departure is a consideration of a series of articles by Keesler.[55,56,57] In 1941 his analysis of opinions of 22 scientists at the University of Michigan revealed that the scientific method is closest to the problem-solving approach and has this plan of organization:

1. Sensing the problem
2. Looking for facts and clues
3. Looking for a hypothesis

4. Testing and using controlled methods whenever possible
5. Selecting the most likely hypothesis
6. Drawing a conclusion
7. Making inferences from the conclusion

Later Keesler indicated that there is no such thing as a single scientific method, but that the problem-solving technique is a close approximation to it. He further noted that the observation of the behavior of students is more important in measuring problem-solving techniques than are paper and pencil tests.

Some of the basic premises and philosophies under which the scientist works as outlined by Keesler[56] are:

1. Desire to experiment
2. Belief in cause and effect
3. Rejection of superstition
4. Care and accuracy in all observations
5. Willingness to change an opinion on the basis of later evidence
6. Determination to be objective
7. Unwillingness to base an opinion on one or too few observations

A more complete list of the basic premises needed in the problem-solving or scientific approach was presented by Van Deventer:[58]

1. Objectivity
2. Tentativeness
3. Relativeness
4. Integration

5. Consistency
6. Uniformity
7. Causality
8. Materiality
9. Dynamism
10. Practicality
11. Continuous discovery
12. Parsimony
13. Social Limitation
14. Complimentarity [sic.]

Many other arrangements of the techniques of problem-solving were found and could have been presented if space permitted.[59-74]

The logical order of the problem-solving method described by Keesler is rarely used, according to Keiffer,[67] but students should be familiar enough with it to make induction and deduction play "leap-frog" with one another.

The review of the literature indicated that one of the places where laboratory work is falling short is in the use of the problem-solving techniques. Lassen[78] noted the small influence of this technique, which has so altered the world, on the solving of problems of our daily living. Richardson[79] criticized science teaching methods as being largely a matter of memorization of content and verification of facts already known, rather than being experimental. Gross and McDonald[65] noted the inappreciable application of the problem-solving objective in the nation's schools, even in science and in mathematics classes.

In brief:

1. Some of the important techniques used by scientists in problem-

solving situations are:[59-74] (1) the search for a possible solution to a problem, need or want; (2) discrimination in the choice of a possible solution; (3) collection of data by observation or experimentation on materials useful to the solution; (4) drawing of conclusions from data to produce a solution; (5) analysis of other problems revealed by the procedure and suitable for further investigation.

2. Failure to solve a problem does not necessarily mean a loss, for other significant problems may have been introduced.

3. Laboratory work can be improved by including more independent work on the part of students, more experiments with unknowns,[37,38] quantitative[88] and "junior research"[96-98] experiments.

4. The laboratory is one of the best places indicated for the development of problem-solving techniques.[76,77]

5. The problem-solving technique should have a larger place in laboratory work.

The Demonstration versus Laboratory Teaching

It was emphasized in the introduction that the demonstration has been mentioned as a possible substitute for laboratory work whenever methods of teaching by individual laboratory were under criticism. Advantages and disadvantages of both methods have been cited in the literature and are briefly reviewed here.

Advantages are claimed for the demonstration:

1. If the principal objective is to impart information or facts.[75]

2. In the opening days of the course to impart essential laboratory techniques.[5]

3. If the goal of teaching is immediate retention.[9,82]

4. For the superior group of a class.[9,82]

5. For teacher control and guidance.[9]

6. If apparatus is complicated, expensive or huge.[83]

7. If pupils are inclined to make mistakes.[83]

8. If a large amount of subject matter is to be covered.[73]

9. If economy in time and expense is a factor.[5,6,7,8]

10. If it prevents "cook-booking."

Teaching by the individual laboratory method of instruction is deemed better:

1. For the inferior portion of the class.[84]

2. If the objective is to learn by doing.[74,75,86]

3. For permanent retention.[9]

4. If experiments are short, not difficult and easy to see.[83]

5. If the objective is to develop laboratory skills or to solve laboratory problems.[83]

6. If the objective is to develop laboratory resourcefulness.[83]

7. For increasing "powers of observation, keenness of initiative, versatility of resourcefulness and effectiveness of cooperation."[74]

8. For opportunities for individual work.[8]

A combination of the two methods (individual laboratory and demonstration) has certain advantages in:

1. The speeding-up of unfamiliar laboratory operations by supplementation with the demonstration.[39]

2. Strengthening the laboratory, by a demonstration.[7,86]

3. Giving the students some variety.[93]

Sometimes laboratory methods are placed in a poor position in comparison with the demonstration technique because:

1. The laboratory instruction needs stepping-up.[87]

2. The best functions of the laboratory are not recognized.[10]

3. The better methods of laboratory teaching are not cited in making the comparison.[10]

4. The outcomes are measured on the basis of knowledge of facts and principles rather than instrumental skills, problem-solving abilities and scientific attitudes.[10]

5. Written tests are used to evaluate the laboratory[9,11] work instead of manipulative tests and practical examinations.

6. No conscious effort is made to bring out the desirable features of laboratory work.[74]

7. Little effort is made to take the laboratory work out of the realm of "cook-booking" and into the realm of problem-solving.

It is evident from the discussion in the literature about the individual laboratory method of teaching versus the lecture demonstration that there is a place for both. Each method of teaching has its advantages and disadvantages. It is significant that in many instances where the laboratory method of teaching is criticized, a faulty technique of measurement is being used or the desirable features of laboratory work are not recognized. In other instances the program of laboratory teaching needs acceleration.

Quantitative Experiments, Unknowns, and "Junior" Research

This section in the review of the literature is included to reveal some of the suggestions for the improvement of chemistry laboratory instruction by means of the use of more of the quantitative type of experiments, more "unknowns" and more of the "junior" type of research.

Gabriel[88] noted that one-third of the experiments in any manual are quantitative, too few call for unknowns and too many are of the "cook-book" type. On the premise that scientific work is exact or precise, he advocated the use of more quantitative experiments.

Farquhar and Ray[89] suggested the establishment of norms based upon the actual practices of students to make the quantitative type of experiments fairer to the students. Bacon[38] advocated a similar procedure and published a list of some of the values. Steiner[90] on the other hand suggested the acceptance of any of the students' results and proposed an evaluation of results based upon the understanding of the experiment.

Both Goff[37] and Gabriel[88] suggested more use of unknowns because they require solution of problems.

The literature search indicated that emphasis on the research type of experiment is not something new, but has been going on over a period of thirty or more years. Anders[91] in 1929, Kirk[92] in 1932 and a symposium[93] in 1930 all indicated the need for more use of research as a teaching tool. Later efforts were made by Summerbell[94] and Delhez.[95] The persistent efforts of the Cortelyou's[96,97,98] from 1936 down to the present time were finally rewarded with the establishment of a national program of "junior" research.

An improvement of laboratory work in chemistry which satisfies the objectives of instrumental and problem-solving skills is indicated by giving more emphasis to the quantitative, unknown and "junior" research type of experiments. An indication of a need for improvement in evaluation of laboratory reports is indicated.

Evaluation of Laboratory Work

The usual methods of evaluation of laboratory work have tended to place laboratory teaching in an unfair position. It has been shown that most testing instruments[9,10,11] measure facts, largely, and are weighted against the laboratory when comparisons with the demonstration are made. It was further noted in the discussion of quantitative experiments above that more precise methods of evaluation are needed. Therefore, this section was introduced to explore briefly some methods of evaluation:

1. Some accurate observations of the activities of each individual student in the laboratory might be made. This is not a highly practical technique.[99]

2. The evaluation of laboratory work must measure the kinds of activity in the laboratory: instrumental skills and problem-solving skills.[28,29]

3. An increased use of the practical examination is advised.[28,99]

4. More emphasis is suggested for the laboratory quiz,[100] and for the formal or essay type of report.[100]

5. Some motivating device such as an imposition of penalties for neglect of good techniques is suggested.[101]

It appears from this review of the evaluation of laboratory work, that much of the criticism of laboratory work is unjustified when the evaluation instruments measure the activities which are peculiar to the work of the laboratory.

Development of Scientific Attitudes

The teaching of chemistry by means of the laboratory has as one of its important objectives the development of scientific attitudes; a brief discussion of this objective is, therefore, in order in closing the chapter on the review of the literature.

Carleton[102] stated, "...when...the laboratory and its emphasis on the investigative research-type exercises disappears from day-in day-out teaching, then the heart and chief inspiration of science as a form of human endeavor has been lost."

A by-product of laboratory work, according to Cope[103], should be important attitudes. Franzen[104] maintained that laboratory work was introduced, in part, to develop scientific attitudes.

Several investigators (Manwiller,[105] Franzen,[104] and Power[106]) noted that scientific attitudes are developed when students come in contact with problems that need to be solved.

According to Hildebrand[140] chemistry is a good subject to impress the elements of character, integrity, accuracy and industry and is unexcelled as the training ground for scientific thinking. Weaver[107] maintained the scientific method could solve problems of economics, society, political science, esthetics, philosophy and regligion as well as problems of sciencie. Zim[108] noted that nothing was as important in science education as "students experiencing science."

Summary

The literature relating to the practices of teaching college general chemistry laboratory has been reviewed with a three-fold purpose: (1) to make a survey of teaching practices, (2) to prepare an annotated bibliography, and (3) to secure items for a questionnaire.

In the chapter itself there is presented a review of teaching practices under seven headings: (1) methods of laboratory teaching, (2) objectives of laboratory teaching, (3) problem-solving, (4) the demonstration versus laboratory teaching, (5) quantitative experiments, unknowns and "junior" research, (6) evaluation of laboratory work and (7) development of scientific attitudes.

An annotated bibliography (Appendix F) was prepared from a selected list of the bibliographic references. The selections chosen were made on the basis of their significance to the investigation as judged by the author.

The items for the questionnaire were selected from a subject index which was prepared from the bibliographic references. The details of the preparation and sampling of the questionnaire are described in Chapter III, the results of the questionnaire in Chapter IV. The questionnaire, as documented from the bibliographic references, is presented in Appendix A.

CHAPTER III

PREPARATION OF THE QUESTIONNAIRE

The second step in this investigation, as expressed in the introduction, was to seek answers to a number of questions suggested by a survey of the literature relating to the practices of teaching college general chemistry laboratory. These questions, when documented and validated, were to appear in the form of a questionnaire. This questionnaire was then to be treated and analyzed to determine results in three categories: (1) objectives of teaching, (2) actual teaching practices, and (3) the awareness of the instructors of certain ineffective teaching practices.

Gathering Items

The process of gathering items for the questionnaire started with an extensive study of the literature concerned with the field of the teaching of college general chemistry. There was accumulated from this study a considerable stock of summarized and classified materials related to this subject. The next process was to select the topics to be included in the questionnaire, and under each topic to select suitable items.

Classifying Items

The items for the questionnaire were secured from the stock of summarized materials mentioned previously. Five main topics were selected for the classification of the items. These were prepared in question form as follows:

1. What are the objectives of laboratory work?

2. What is the nature or status of present day laboratory work?

3. What are some of the improved methods of laboratory teaching?

4. What will improved methods of laboratory teaching do to the current methods of teaching?

5. What questionnaires have previously been used to study practices of laboratory teaching?

The items were then withdrawn from the stock of summarized materials and classified under these five headings. Duplicate items were eliminated, and the items that remained constituted the preliminary questionnaire.

Validating the Items

The preliminary questionnaire was then validated through a series of steps.

Submission to Graduate Committee. The first step in validating the preliminary questionnaire was its submission to the graduate committee appointed by the Dean of the Graduate School. The committee suggested the elimination of some items and the grouping of other items under subheadings. The changes were made and the revised questionnaire was re-submitted to this committee. Further elimination of items and more grouping under subheadings was suggested, as well as making a revised preliminary questionnaire with five main headings: (1) objectives of laboratory teaching, (2) details of the actual practices of laboratory teaching, (3) some of the criticisms of current practices of teaching, (4) some suggestions for improving teaching practices and (5) some of the results which might be expected from use of improved teaching methods.

Re-classification of Items. The items of the preliminary questionnaire were re-classified under the five headings suggested above.

Submission to Board of Experts. The preliminary questionnaire as revised was submitted to a board of experts. The board was composed of three professors from Montana State College and two from Eastern Montana College of Education.

The board of experts offered much constructive criticism, and made a number of suggestions. The principal suggestions made were to reduce the number of items, shorten the questionnaire, and use but three main parts: (1) objectives of teaching, (2) actual practices of teaching and (3) some of the criticisms of current teaching practices.

Revising the Questionnaire

The final revision of the questionnaire was made according to the suggestions and was approved by the chairman of the graduate committee. A final draft was then prepared and put in printed form. A copy of this final draft, as documented from the items originally prepared, appears in Appendix A. It consists of three parts, and has as its objective the gathering of information in these three categories: (1) objectives of laboratory teaching, (2) actual practices of laboratory teaching, and (3) awareness of the instructors of certain criticisms of present practices of laboratory teaching.

Mailing the Questionnaire

The final draft of the questionnaire was then ready for mailing. As was indicated in the introduction, the questionnaire results, to be characteristic of the general population of those practicing the teaching of college general chemistry laboratory, must be representative of the whole population. Therefore, all the four-year accredited colleges teaching college general chemistry laboratory in the four-state region of Idaho, Montana, Oregon and Washington were sampled. The inclusion of all these institutions, as defined, assured a representative and random sampling that could be extended to a larger region which would include more of such institutions.

Two sources of information were used to secure the names of the institutions, and the names and addresses of the department chairmen for mailing. The names of the accredited colleges and universities were taken from the 1957 Report of Credits Given by Educational Institutions for the American Association of Collegiate Registrars and Admissions Officers.[109] The names and addresses of department chairmen were taken from the college catalogs of the various four-year accredited institutions in the four-state area. This information is summarized in Table 1.

Copies of the questionnaire were then mailed to the department chairmen.

Table 1. COLLEGE OR UNIVERSITY, LOCATION, AND NAME OF DEPARTMENT CHAIRMEN WHO WERE SENT COPIES OF THE QUESTIONNAIRE

College or University	Location	Chemistry Department Chairmen
	Idaho	
College of Idaho	Caldwell	A. K. Stuenberg
Idaho State College	Pocatello	E. J. Baldwin
Northwest Nazarene College	Nampa	G. C. Ford
University of Idaho	Moscow	W. H. Cone
	Montana	
Carroll College	Helena	D. G. Waldhalm
College of Great Falls	Great Falls	F. W. DiRocco

Table 1. (Continued)

College or University	Location	Chemistry Department Chairmen
Eastern Montana College of Education	Billings	W. F. Clark
Montana School of Mines	Butte	K. N. McLeod
Montana State College	Bozeman	W. B. Cook
Montana State University	Missoula	Earl Lory
Northern Montana College	Havre	F. Yeager
Rocky Mountain College	Billings	G. F. Wannfried
Western Montana College of Education	Dillon	H. Smith
	Oregon	
Cascade College	Portland	L. V. Corbin
Eastern Oregon College	LaGrande	G. W. Slabaugh
Lewis and Clark College	Portland	W. N. Sherrer
Linfield College	McMinnville	L. R. Taylor
Marylhurst College	Marylhurst	Sister Gertrude Marie
Mt. Angel Women's College	Mt. Angel	F. P. Bluemmel
Oregon College of Education	Monmouth	E. F. Barrows
Oregon State College	Corvallis	E. D. Christensen
Pacific University	Forest Grove	H. Schimke
Portland State College	Portland	*
Reed College	Portland	A. F. Scott
Southern Oregon College	Ashland	C. E. Diebel
University of Oregon	Eugene	F. J. Reithel
University of Portland	Portland	W. S. MacGregor
Willamette University	Salem	C. H. Johnson
	Washington	
Central Washington College of Education	Ellensburg	E. L. Lind
College of the Puget Sound	Tacoma	P. R. Fehlant
Eastern Washington College of Education	Cheney	D. E. Harter
Gonzaga University	Spokane	Rev. A. L. McNeil
Holy Names College	Spokane	Sister M. Febronia

Table 1. (Continued)

College or University	Location	Chemistry Department Chairmen
Pacific Lutheran College	Parkland	A. W. Ramstad
St. Martin's College	Olympia	*
Seattle University	Seattle	Rev. G. R. Beezer
Seattle Pacific College	Seattle	B. R. Dietzman
University of Washington	Seattle	P. C. Cross
Walla Walla College	Walla Walla	G. W. Bowers
Washington State College	Pullman	J. L. Culbertson
Western Washington College of Education	Bellingham	F. W. Knapman
Whitman College	Walla Walla	L. C. Humphrey
Whitworth College	Spokane	*

*College catalog not available at time questionnaire was mailed, hence name of department chairman was omitted.

Assuring the Return of the Questionnaire

An effort was made by mail and by personal contact to secure at least one completed copy of the questionnaire from each of the colleges or universities. The data on the returns (Table 2) show that at least one copy of the document was returned by more than 93 percent of these institutions. One hundred percent of the colleges of Idaho, Montana and Oregon and 80 percent of the institutions in Washington returned questionnaires.

The next step in the investigation was to tabulate and analyze the questionnaire results in the following three categories: (1) objectives of laboratory teaching, (2) current practices of teaching and (3) awareness of the instructors of certain ineffective teaching practices in chemistry laboratory.

Table 2. QUESTIONNAIRE RETURNS BY COLLEGES AND BY STATES

Classification of Returns	States				Total
	Idaho	Mont.	Oregon	Wash.	
No. of colleges and universities sent questionnaires	4	9	15	15	43
No. of colleges and universities returning questionnaires	4	9	15	12	40
Percentage of colleges and universities returning questionnaires	100	100	100	80	93+
No. of copies of the questionnaire returned	6	20	27	18	71

CHAPTER IV

CURRENT PRACTICES IN THE TEACHING OF COLLEGE GENERAL CHEMISTRY LABORATORY

The purpose of this investigation was to determine the current practices in the teaching of college general chemistry laboratory from an analysis of the results of the questionnaire. The practices were presented in three classifications: (1) objectives, (2) actual teaching practices, and (3) criticisms of certain teaching practices. The results were compiled from the treatment of 71 copies of the questionnaire which came from 40 different colleges and universities.

The Objectives of Teaching

The purpose of this part of the investigation was to find out which objectives in the teaching of college general chemistry were considered to be the important teaching objectives. In the questionnaire there was a list of teaching objectives and the instructions called for the ranking of these objectives according to the scale: (1) excellent goals--the principal reasons for teaching, (2) average goals--not the most important but good enough to be included, and (3) poor goals--irrelevant--could be removed from the list.

The ranking of the goals formed the basis for the preparation of frequency charts in the form of tables. The importance of a goal as a teaching objective in college general chemistry laboratory was decided on the basis of the number of times the rank number of that goal was selected. The following techniques were used to assist in judging the importance of the goals:

1. The ranking of a particular goal was made by a comparison of the magnitude of the frequencies of selection of the rank numbers.

2. A two-class system or dichotomy was set up if the frequency of the selection of one of the rank numbers was zero or if two of the three ranks could be combined into a single rank. The selection of the rank numbers was treated for randomness by assuming the Null Hypothesis.*[157]

---

*Under the Null Hypothesis, hereinafter called H_o, the assumption was made that little difference existed in the frequency of selection of either member of the dichotomy. A value, z, was then calculated. Z was the deviation of the observed value from that of the population mean when sigma (σ) is equal to one. $z = \frac{(x + 0.5) - NP}{\sqrt{NPQ}}$, where N = the total number of independent observations, x = the value of the smaller member of the dichotomy, P = the proportion of cases expected in one member of the dichotomy (here P = 1/2) and Q = the proportion of cases expected in the other member of the dichotomy (here Q = 1/2).

The probability of acceptance of H_o was estimated from the value of z. It was accepted if the probability was greater than 0.01 and rejected if less than 0.01. If rejected, the alternate hypothesis, that the frequency of the selection of rank numbers was significant, was accepted. The choice of the proper rank number was then made by a comparison of the magnitudes of the frequencies of selection of the rank numbers.

If H_o was accepted, it was assumed that there was little difference in the selection of a rank number for a particular goal. Further details in the calculation of z were presented in Appendix C.

If the frequencies of selection were significant, the choice of a rank number for that goal was judged as explained under number one above.

3. The Chi^2 technique * was used to assist in the determination of the importance of a teaching goal under certain specific conditions:[157] (1) if the frequency of selection of the rank numbers for a given goal was not zero and (2) if not more than 20 percent of the expected frequencies

---

*The Chi^2 technique was used to determine the significance of the frequencies of selection of the rank numbers for the goals by first assuming H_o as in the case of the dichotomy. Chi^2 and df (the number of degrees of freedom) were calculated from the following formulas: $Chi^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i}$, where O_i = the observed number of cases, E_i = the expected number of cases; $\sum_{i=1}^{k}$ directs a summation over all (k) categories, and df = k-1, where df = the number of degrees of freedom and k = the number of categories.

Chi^2 is a random value which follows a special distribution (See 157). From its value and the value of df, the probability of acceptance of H_o was determined. H_o was accepted if the probability was greater than 0.01 and rejected if less than 0.01. If H_o was rejected, the alternate hypothesis, that the frequency of selection of the rank numbers for a given goal was significant, was accepted.

When it has been determined that the selection of the rank numbers was significant, the choice of the proper individual rank number for a given goal was made by a comparison of the magnitudes of the frequencies of selection of same.

If it has been determined that the selection of the individual rank number was not significant, the assumption was made that little difference existed in the choice of a rank number for that particular goal.

Further details concerning the use of the Chi^2 technique were presented in Appendix C.

for an individual rank number for a given goal had a numerical value less than five. If the conditions were favorable, the selection of the rank numbers was treated for randomness by assuming the Null Hypothesis, H_o, and making use of the Chi^2 technique. Rejection of the Null Hypothesis indicated that the selection of the rank numbers was significant.

The first objective to be treated was concerned with the matter of information or facts.

Information or Facts (Topic A). An over-emphasis on information or facts was noted in the literature review. Hence it was desired to find the relative importance of information or facts as objectives in the teaching of college general chemistry laboratory.

The results of the questionnaire were presented in Table 3, and the selection of the goals* for the objective of information or facts was as follows:

Accepted as excellent goals:

Knowledge of facts and principles. (No. 1)
Preparation for advanced training. (No. 5)
Reality of the descriptive facts. (No. 6)

Accepted as a poor goal:

History of chemistry. (No. 3)

---

*The method used for the selection of each of the goals for the general objectives was done according to the plan presented in Appendix D.

Neither accepted nor rejected as goals:

Library search for chemical information. (No. 2)
Liberal arts or general chemistry. (No. 4)

Concepts, Principles, Theories (Topic B). The purpose of this section of the questionnaire was to find the important goals under the objective of concepts, principles and theories. The data and results were shown in Table 4 and summarized as follows:

Accepted as excellent goals:

Verification of principles by performance of experiments. (No. 8)
Reality of theories, concepts or principles learned. (No. 9)

Accepted as excellent or average goals:

Proving ground where concepts and principles were tested. (No. 10)
Observations upon which principles were developed. (No. 11)

Instrumental Skills (Topic C). Under the objective of instrumental skills the aim was to determine which of the skills listed were important as goals for the teaching of college general chemistry laboratory. The results were indicated in Table 5 and the findings summarized below:

Accepted as excellent goals:

Observation, first hand, of substances, reactions and basic principles of chemistry. (No. 15)
Orderly habits. (No. 16)
Quantitative observation and experimentation. (No. 17)

Accepted as excellent or average goals:

Manipulative skills and techniques. (No. 13)

Accepted as average goals:

Technical training. (No. 18)
Resourcefulness. (No. 21)

Accepted as poor goals:

Specialized training. (No. 19)
Professional training. (No. 20)

Neither accepted nor rejected as goals:

Work with the hands at new and strange tasks. (No. 14)
Idealized experimentation. (No. 22)

An additional check on the significance* of the findings for the goals under the objective of instrumental skills was made. This was done by the calculation of a Contingency Coefficient from the value of Chi^2 for all the goals under this heading. The Contingency Coefficient, $C = 0.53$, indicated that the findings presented were significant.

---

*The significance of the selection of the goals was further checked by the determination of Chi^2 and the degrees of freedom (df) for all the goals under one objective. H_o was assumed. A Contingency Coefficient, C, was calculated from Chi^2 by the following formula: $C = \sqrt{\frac{Chi^2}{N + Chi^2}}$, where N was the number of frequencies in the entire Topic. C was a measure of the "extent of association between two sets of attributes." [157] In this case the two sets of attributes were the rank numbers and the goals of laboratory teaching. Since the limits of C occur between 0 and 0.82, a value of $C = 0.53$ indicated the selections made were significant and not just chance selections.

The probability of acceptance of H_o for the entire Topic C, with a calculated Chi^2 of 198.7 with 16 degrees of freedom, was less than 0.001. H_o was rejected and the alternate hypothesis of the significance of the findings was assumed.

Problem-Solving Skills (Topic D). The survey of the literature indicated that problem-solving skills were important as teaching objectives. The question was to discover which of the skills listed were important. The results were summarized in Table 6, and the findings presented here:

Accepted as excellent goals:

The scientific or problem-solving method. (No. 24)
Quantitative thinking. (No. 26)

Accepted as average goals:

Generalization from the specific. (No. 25)
Validation of conclusions. (No. 27)
Solution of laboratory problems. (No. 28)

A Contingency Coefficient, C = 0.23, indicated that the selections made for the goals under the objective of problem-solving skills were significant.

Attitudes (Topic E). The aim was to find out which attitudes were important as objectives in the teaching of college general chemistry laboratory. Table 7 contained the results, and the findings were summarized as follows:

Accepted as excellent goals:

Scientific attitudes. (No. 30)
Original and creative thinking. (No. 32)

Accepted as excellent or average goals:

Interest in the spirit of discovery. (No. 31)