DODSON, B C, 1924-
THE STATUS OF INTRODUCTORY COLLEGE CHEMISTRY IN ACCREDITED COLLEGES AND UNIVERSITIES.

The University of Oklahoma, Ed.D., 1969
Education, teacher training

THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

THE STATUS OF INTRODUCTORY COLLEGE CHEMISTRY IN ACCREDITED COLLEGES AND UNIVERSITIES

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF EDUCATION

BY

B C DODSON

Norman, Oklahoma

1969

THE STATUS OF INTRODUCTORY COLLEGE CHEMISTRY IN

ACCREDITED COLLEGES AND UNIVERSITIES

APPROVED BY

John W Renner

Herbert R. Hengst

Bernard O. Heston

Sherril D. Christian

DISSERTATION COMMITTEE

PREFACE

The observation is not new, neither is it unconfirmed by others, that there is a diversity of opinion as to what course content should be taught in introductory college chemistry, how it should be taught, and what materials should be used. The primary contention now seems to be to consolidate these diverse opinions and practices and attempt to ascertain some order out of the controversies and diversity.

A few investigations have been directed at determining the objectives of general college chemistry, the course content of introductory college chemistry, and motivation practices in first year college chemistry. These noteworthy attempts have been meager when compared to the prolific writing of chemistry educators describing the objectives and content of courses taught at their respective institutions of higher education. The Advisory Council on College Chemistry has described a course directed at the university level. The question is asked, "Do introductory college chemistry courses directed at the university meet with the needs of other institutions of higher learning, namely, the liberal arts colleges and the junior colleges?" The literature is abundant with articles showing a diversity of teaching practices but few solutions are offered.

Fully cognizant of the damage of oversimplification and distortion of meaning, an attempt will here be made to consolidate these previous writings, suggestions, and research findings. This is in order to obtain a clear cut view of what current objectives, teaching methods, and materials are being used in the accredited colleges and universities.

ACKNOWLEDGEMENTS

The investigator is especially grateful to Dr. John W. Renner, the University of Oklahoma, for his perceptive and skillful guidance throughout the dissertation and for his patience and assistance during the time in which the dissertation was developed.

The United States Department of Health, Education, and Welfare is accorded a kind thank you for their unceasing encouragement and their financial assistance in gathering the data for this survey.

Finally, to my family and especially my wife, who each in his own manner contributed heartily and unselfishly to the completion of the dissertation, goes an expression of infinite thanks.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

THE STATUS OF INTRODUCTORY COLLEGE CHEMISTRY IN ACCREDITED COLLEGES AND UNIVERSITIES

CHAPTER I

PROBLEM AND OBJECTIVES

Statement of the Problem

The purpose of the survey is to determine the present objectives, teaching methods, and materials used in teaching the introductory course in college chemistry in selected accredited colleges and universities in the continental United States. The investigation was directed at current objectives, methods, and materials with respect to the various colleges and universities.

Procedure Used in the Study

The procedure used in the survey was an examination of the teaching practices used by instructors in the teaching of introductory college chemistry in selected accredited colleges and universities by means of a questionnaire.

Scope and Limitations of the Survey

There are approximately 1,636 accredited institutions of higher education that offer introductory college chemistry, but the results of this study must be limited to the sample of 351 accredited colleges and universities in the continental United States.

The second limiting factor is that the sample for the survey was selected from only those colleges which grant chemistry credit in the first-year college chemistry course. The survey is concerned with a widely dispersed population; and, since many colleges and universities are involved and their courses vary in content and thoroughness, this investigation is specific and directed at selected accredited colleges and universities. Any conclusions are general only in so far as the same conditions pertain to other colleges as were present in the colleges studied.

Population of the Survey

The population for this survey consists of 351 accredited institutions of higher education. The investigator found that several institutions have either replaced introductory college chemistry with a course in Science Fundamentals or have replaced it with a multidiversity science course. In some instances, the introductory college chemistry course has become an integral part of a comprehensive physical science course. For the purpose of this survey, only courses in introductory college chemistry which specifically carry credit in chemistry were considered. Courses in the philosophy of science, fundamentals of science, and chemistry courses designed specifically for non-science major are not included in the survey.

Definitions and Interpretations

The Critical Ratio (t-test) is a statistical measure used to determine whether a significant difference exists in a particular trait between two comparable groups. It is obtained by dividing the difference between the means of the groups of those traits by the standard error of difference between the means.

The Standard Error of Difference Between the Means is obtained by dividing the standard deviation from the mean of the college enrollment by the square root of the number of colleges in a given strata.

The Stratified Random Sample is achieved whenever a population, such as the total number of colleges, is divided into subgroups and some kind of random sample is taken in each group.

Strata is the subgroup from which the random sample is drawn.

Stratification is the process of dividing the population into groups.

Method of Optimum Allocation is the allocation of sample size in the respective strata for a fixed total sample size when the sampling variance is minimum. If previous information is available for approximating both the size of the strata and the variances of the characteristics within the strata, it is possible to allocate sample units among the strata.

Optimum Allocation concerns the choice of the sample sizes in the respective strata. Optimum allocation states that the sample size in a stratum should be proportional to the product of the size of the stratum and the standard deviation of the stratum, or in other words that the sampling fraction should be proportional to the standard deviation. The allocation of sample size in the respective strata is said to be optimum for a fixed total sample size when the sampling variance is minimum.

Trend may be considered as a general prevailing movement, changing in a specific and indicated direction, and thus reflecting a recognizable change of tendency or emphasis.

Accredited Institutions are those institutions of higher education in the continental United States that are accredited by the nation's six regional associations of schools and colleges as listed on page vii of the *Accredited Institutions of Higher Education*, September, 1967, American Council on Higher Education, Washington, D. C.

Introductory College Chemistry refers to the first-year college chemistry course which receives credit under the title "chemistry" and meets the prerequisite requirement for further chemistry courses in a college curriculum.

CHAPTER II

THE NEED FOR THE SURVEY

Introduction

This chapter contains ideas and information obtained from reviewing the literature--research and theoretical--relevant to the proposed survey. Specifically, the investigator will principally show the diversity of opinion among the professional chemistry educators that have implicitly permeated the teaching of the first-year college chemistry course (the introductory college chemistry course) and the history of that diversity.

Although several investigations have been directed at determining the objectives of the introductory course in college chemistry,[1] several surveys have attempted to delineate the course content in introductory college chemistry;[2,3] and a few educators have attempted to describe motivation practices[4] in general college chemistry. According to the titles of articles and abstracts in the Journal of Chemical Education, Chemical

---

[1]Otto M. Smith, "Accepted Objectives in the Teaching of General College Chemistry," Journal of Chemical Education, 12 (1935) p. 182.

[2]H. J. Nechamkin, "The Course Content of General Chemistry," Journal of Chemical Education, 38 (1961) p. 255.

[3]Jay A. Young, "The Content of the First Course in College Chemistry," Journal of Chemical Education, 41 (1964) pp. 477-478.

[4]Robert K. Summerbell, "The Excitement of Experiment," Journal of Chemical Education, 41 (1964) p. 126.

Abstracts, Education Index, and Dissertation Abstracts, there have been no surveys published that combine the aforementioned investigations and the teaching practices used in the introductory college chemistry course. The findings and conclusions of these investigations have been meager when compared to the numerous writings of the professional chemistry educators either in their individual descriptions of their own respective chemistry curriculum or the expoundings of their own personal satisfaction or dissatisfaction in regard to course objectives and the ensuing criticisms in regard to their own course and/or student evaluation.[5] In general, these writings and survey findings are inherent of one common ingredient; they either show a controversy or express a diversity of opinion among the professors of chemistry. The diversity of opinion among the members of the chemistry profession as to selection of what course content should be taught in introductory college chemistry, how and in what sequence these concepts should be taught, and what supplementary materials should be used is not new; neither is it unconfirmed by others.[6] One major question which has emerged from the variation and diversity is "Do introductory college chemistry courses designed at the university level meet the needs of other institutions of higher education, namely the liberal arts colleges?"[7] An answer to this question is imperative since the

---

[5]Symposium, "Recent Trends in Undergraduate Chemistry Curricula," Journal of Chemical Education, 41 (1964), pp. 126-147.

[6]Edward L. Haenisch, ed., The Content of Introductory College Chemistry, Wabash College, Indiana: Advisory Council on College Chemistry, December, 1964, p. 5.

[7]Nelson McKain, Jr., "Rigor or Breadth for Freshmen," Chemical and Engineering News, 42, March 23, 1964, p. 4.

Advisory Council on College Chemistry has shown statistics that indicate a transfer of 25 percent of two-year college students to either universities or four-year institutions.[8] The current revision activities with resultant emphasis on the individual practices and opinions of individual educators and/or individual institutions regarding the nature and characteristics of what these educators think the introductory college course should be have resulted in so many various and uncorrelated curricula changes. Some of the college educators believe that the revision activities are being redirected toward a redefinition of the scope of the undergraduate chemistry training, toward a reformulation between chemistry and related fields, and toward a remodeling of new teaching materials and the resulting introduction of new concepts.[9] Others feel that the consequence of these course modifications is such that no one really knows just what the nature of the introductory course in college chemistry is at present.[10] Furthermore, there are no agreed upon standards of content for the introductory college chemistry course and, as a result, local and/or national evaluation is difficult.[11] The investigator believes that the evidence warrants, in part, characterization of the situation by saying that the professional chemistry educators do not know what they really want to do in introductory college chemistry.

---

[8]Haenisch, p. 5.

[9]"Recent Trends in Undergraduate Chemistry Curricula," p. 126.

[10]Robert I. Walter, "The Changing Curriculum in Chemistry: Some Contemporary Developments," Journal of Chemical Education, 42 (1965), p. 524.

[11]Richard G. Yalman, "Chemistry in Liberal Arts Colleges," Journal of Chemical Education, 41 (1964), p. 145.

The literature review of experimental curricula[12] shows, in many cases, that the local evaluation practices of the introductory college chemistry courses have shown such illusive criteria as (1) the enthusiasm of professors about their own chemistry program and the transmission of this exhilaration to the students; (2) the number of students who have survived the ministrations; (3) the curricular changes that have proved stimulating to the professors; (4) the consensus of the staff and teaching assistants that the new changes are quite effective and deserve approbation; (5) the student enjoyment in doing laboratory experiments and their appreciation and respect for the expensive equipment used; and (6) the success of the course revision is judged upon the number of students entering chemistry as a major field or being prepared for other professional careers which incorporate chemistry as a supporting field.

A direct implication of some chemistry educators is that it is time the teaching profession began to think of essential objectives for chemistry and flexibility in evaluating whether or not these stated objectives have been achieved.[13] The development of course practices has been so numerous and the differences of opinion so varied that the Advisory Council on College Chemistry (AC_3) has held conferences to study content of freshman chemistry courses. AC_3 has also been studying some of the other major problems confronting introductory college chemistry professors. The Council, at present, is seeking answers to the following questions:

(1) What science, if any, should be taught nonscience majors?
(2) What topics should be taught to chemistry majors?
(3) What new teaching aids, if any, will combat successfully

---

[12]David N. Hume, Experimental Curricula in Chemistry, Advisory Council on College Chemistry. Wabash College, Indiana: October, 1963.

[13]Ibid., p. 144.

the onslaught of increasing enrollments?
(4) Should freshman chemistry courses be redesigned along broad topical lines such as dynamics, structure, and synthesis?
(5) What is the future role of liberal arts colleges and junior colleges in chemical education?[14]

None of these questions has been fully answered, but some of the AC_3 Council members have expressed guarded optimism that partial answers are now available.

The present era is also characterized by a plea for an analysis of first-year college chemistry teaching practices.[15,16,17] In addition to aims and objectives, the teaching methods and materials used in the beginning college chemistry courses have been, and are, a matter of concern. Interestingly enough, however, the objective surveys in this field of investigation have been few, and these have been open to criticism.

Probably the only consistency in the replies to the question, "What are you doing in the first-year chemistry course?" is the universal dissatisfaction with what has been done and the variety in the proposals tried or planned in the near future.[18] Perhaps the present concern for an analysis of teaching practices as well as course objectives and evaluation emanates from the variety of programs being implemented at each individual university or college.

---

[14]"AC_3 Zeros in on Chemical Education," Chemical and Engineering News, 44, August 1, 1966, pp. 40-41.

[15]William C. Morgan, "Symposium: What Are Our Objectives Teaching Chemistry?" Journal of Chemical Education, 2 (1925) pp. 971-975.

[16]Yalman, p. 142.

[17]Laurence E. Strong, "College Chemistry--The Road to Nonsense or Science," Chemical and Engineering News, 43, February 22, 1965, p. 128.

[18]"Editorially Speaking," Journal of Chemical Education, 41 (1964) p. 115.

Historical Background

At the beginning of the nineteenth century, introductory college chemistry was taught by a combination of textbook readings and didactic instruction. Lectures on college chemistry in the United States were given at Amherst, Brown, Harvard, Rensselaer, West Point, and other colleges and universities.[19] A widely distributed textbook designed to accompany these lectures was edited by John M. Webster, Erving Professor of Chemistry and Mineralogy at Harvard. His lectures and textbooks were typical of the time and covered the entire range of chemical knowledge including Dalton's atomic theory, laws of definite and multiple proportions, equivalent weights, the chemistry of the elements, organic, physiological and analytical chemistry.[20]

In the years following the Civil War, a force appeared on the American collegiate scene that revolutionized instruction of first-year college chemistry. The outgrowth of the return of a large number of American students from German universities caused a very noteworthy change--the introduction of laboratory work to accompany the lecture and the textbook.[21] The typical procedure which evolved was to teach first-year college chemistry by a combination of laboratory work, textbook and didactic instruction carried on simultaneously, with at least one half of the time devoted

[19] Frederick Rudolph, The American College and University, New York: Vintage Books, 1962, pp. 222-223, 225, 227, 229-231.

[20] Yalman, p. 142.

[21] J. O. Frank, The Teaching of High School Chemistry, Oshkosh, Wisconsin: J. O. Franks and Sons, 1932, p. 8.

to laboratory work. Woodburn and Obourn[22] have characterized the textbooks of this post Civil War period to be organized around the logic of subject with practically no attention devoted to the psychology of learning.

Philosophically, there was evidence early in the post Civil War period to indicate that a few educators were shifting from the theoretical and factual method of teaching to the inductive or experimental method of teaching. Evidence of this trend was found in the preface of the Elementary Manual of Chemistry, 1872, by Eliot and Storer. They favored the experimental and inductive method to teaching chemistry when they wrote:

> The authors object is to facilitate the learning of chemistry by the experimental and inductive method, to develop and discipline the observing faculties.[23]

Later, Storer and Lindsley reinforced the view that chemistry should be taught by the experimental and inductive method by stating:

> The student acquaints himself with facts and principles through attentive use of his own perceptive faculties.[24]

The emphasis on the experimental method of teaching was soon to change, however. Toward the end of the last decade of the nineteenth century, there were some evidences of a general distrust of the inductive method as shown in the forthcoming comments of Carhart and Chute when they wrote:

> A few years ago it seemed necessary to urge upon teachers

---

[22]John Woodburn and Ellsworth S. Obourn, Teaching the Pursuit of Science. New York: MacMillan Company, 1965, p. 194.

[23]Eliot and Storer, in Woodburn and Obourn, Teaching the Pursuit of Science. New York: MacMillan Company, 1965, p. 192.

[24]Storer and Lindsley in J. D. Steele, Fourteen Weeks in Chemistry. New York: A. S. Barnes and Company, 1873.

> the adoption of laboratory methods to illustrate the textbooks; in a few instances it would seem almost necessary to urge the use of a textbook to render intelligible the chaotic work of the laboratory. ... the pupil should be kept in his classwork well ahead of the subjects forming the basis of his laboratory experiments.[25]

A Survey of the History of the Controversy in Introductory College Chemistry

This ensuing controversy over the laboratory objectives and the sequence order of experiments when placed in juxtaposition with textbook content appears to have set the stage for a controversy regarding difference in opinion over course objectives and course content. An objective appraisal of the period from 1872-1900 would have to acknowledge a genuine attempt to upgrade the teaching of chemistry through the improvement of laboratory work. This circumscribing thought, coupled with the cited charge of Woodburn and Obourn[26] that the introductory college curriculum in the closing years of the last decade of the nineteenth century had resulted in authoritarian teaching by deductive methods, probably is indicative of a new era in the psychological and pedagogical position as to the teaching of introductory college chemistry. This trend is also further exemplified by Yalman's assertion that chemical education, around 1910, was following classical lines; i.e., as the body of knowledge increased, systematic branches of chemistry appeared and so did the proliferation of chemistry courses.[27]

---

[25]Carhart and Chute, in Woodburn and Obourn, Teaching the Pursuit of Science. New York: MacMillan Company, 1965, p. 193.

[26]Woodburn and Obourn, p. 194.

[27]Yalman, p. 143.

Prior to and succeeding World War I, forces began to emerge which caused the chemistry professors to shift their chemistry offerings to meet new demands. According to Merwin,[28] these influential forces were the seven cardinal principles of secondary education, 1918,[29] the final report of the Committee on Sciences of the Commission on the Reorganization of Secondary Education, 1920,[30] and Frederick J. Kelley's study of the liberal arts colleges.[31] The Seven Cardinal Principles listed objectives of education and the Committee on Sciences endorsed and recommended general chemistry for various curricula. Kelley's study called attention to the need for definite aims and made some suggestions, which in some cases, at least, appear to have stimulated and served as guides for the selection of additional courses in freshman chemistry. The combined influences of these forces produced a strong shift to the practical, the useful, in all school subjects; and an attempt was made to offer those subjects that will best fit the student for life in his community. First-year college chemistry courses and specialized chemistry courses were recommended for various curricula such as household chemistry and industrial chemistry. The first-year college chemistry course, as a result of these forces, was considerably modified. The time devoted to laboratory was lessened and

---

[28]B. W. Merwin, "Development of the Curriculum in College Chemistry," Journal of Chemical Education, 12 (1935), p. 543.

[29]Cardinal Principles of Secondary Education. Bulletin No. 35. Washington: Department of Interior, Bureau of Education, 1918.

[30]Otis W. Caldwell and Committee, Report of the Subcommittee on the Teaching of Science, Bulletin No. 26. Washington: U. S. Bureau of Education, 1920, pp. 12-13.

[31]Kelley in Merwin, p. 543.

the time allotted for demonstration work was increased, while the disciplinary aim became the preparation of a student for life in the community in which he lived.[32] Professors directed their attention to pressing problems which were the results of the forces mentioned above compounded with the interest of a few to retain the inductive methodology. One of the most controversial areas, at that time, was the subject of correlation of high school and college chemistry. The criticisms became so numerous that the American Chemical Society appointed a Committee on Chemical Education to study the correlation of high school and college chemistry. In addition, another controversy developed from the issues resulting from pedagogical practices in laboratory work--the individual laboratory versus the demonstration laboratory.[33] In spite of these ramifications, the plea for objectives did not subside.

Objectives of General Chemistry

One of the most controversial areas of conflict among the chemistry educators is concerned with objectives, both local and national. Chemistry professors have always had objectives in chemical education, whether good or bad. These objectives are stated in textbooks, syllabi, curriculum guides, symposia, and suggestions of the Advisory Council on College Chemistry. The general objectives usually include statements to the effect that the student is to gain an understanding of the fundamental concepts of chemistry; the student is to increase in the ability to think critically; and the student is to understand relations between chemistry

---

[32]Ibid.

[33]R. L. Cooke, "Demonstration Versus Laboratory Once Again," Journal of Chemical Education, 15 (1938) p. 592.

and society. These objectives sound good, but do they really provide a direction to what students need to do? Objectives need more specific outcomes. "To gain an understanding of the fundamental concepts of chemistry" is much too vague. Objectives should imply teaching processes and methods of evaluation.[34] The evidence is far from conclusive that chemical educators have alluded to any ground rules or frame of reference when discussing or making pleas for course objectives. Perhaps the renewed concern for objectives, as well as aims, emanated from the controversy over correlation of course content and the selection of laboratory methods. The growing concern for establishing specific objectives in general college chemistry was reflected by William C. Morgan, in 1925, in his introductory speech to a symposium entitled, "What Are Our Objectives in Teaching Chemistry?" Morgan further exemplified the controversy and literally took the college chemistry teacher to task by stating:

> John Dewey, one of the greatest educators the world has ever produced, has repeatedly stated that science offers nothing so valuable to mankind as a knowledge and appreciation of the scientific method. In one of the most significant books that have been published in recent years, James Harvey Robinson maintains that rational thinking (or the scientific method) has contributed more to the advancement of mankind than all other human efforts put together, and that nothing is now so important in education as a knowledge of its past accomplishments and future possibilities. Yet in the report of "A Standard Minimum High-School Course in Chemistry" there is no mention of the scientific method. Apparently, "a prophet is not without honor save in his own country."[35]

In his concluding remarks, Morgan issued the following challenge:

> What are we trying to do in teaching chemistry? Shall we

---

[34]Earl T. Montaque and David P. Butts, "Behavioral Objectives," <u>The Science Teacher</u>, <u>35</u>, March, 1968, pp. 33-35.

[35]Morgan, p. 971.

> endeavor to make of the minds of our students depositories of information in which the moth of forgetfulness and the rust of disuse will corrupt the facts? Shall we not teach them rather to know books and use libraries which will in time of need furnish them with exact information in a thousand-fold greater abundance than any one mind can comprehend? Shall we not strive to develop mental laboratories and teach the use of their equipment so that every last one of our students may realize the value of evidence and to some extent how to obtain it?[36]

The same year, C. H. Desch also expressed a similar view of the purpose of general chemistry when he remarked:

> Chemistry is an experimental science which progresses by the application of a definite discipline, obtaining conclusions by induction from the observed facts and making use of deduction from a small number of well-tried hypotheses where required.[37]

Apparently, two more prophets were without honor in their own countries. Other professors tried to redirect chemical educators back to a statement of objectives. The emphasis had shifted away from course objectives to the subjects of correlation of high school and college chemistry and the content of general college chemistry, the controversy regarding the contributions of high school chemistry toward success in the college chemistry course, and the debate on which method of laboratory instruction is needed in introductory college chemistry. An attempt was made by W. A. Noyes, Jr., to consolidate objectives and course content when he expressed concern for the quality of the chemistry graduate by writing:

> The lack of properly trained chemists is due to first, the scheme of training, second, to the type of teacher too commonly found in our colleges and finally, the low and uncertain standards of a large number of our schools. ... More objective standards are needed that they may be more uniformly applied

---

[36]Ibid., p. 975.

[37]C. H. Desch, "The Discipline of Chemistry," Nature, 116 (1925) pp. 504-505.

throughout our systems of colleges.[38]

The neglect of course objectives was only transient, however. Otto M. Smith, Oklahoma State University, 1935, redirected the chemistry educators back to the importance of course objectives when he wrote:

> It was felt that the desirable content of general chemistry was sufficiently covered by the Committee on the Correlation of High-School and College Chemistry in their list of topics for a minimum high-school course in chemistry. 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 the subject matter but the ability to meet situations and to solve them that constitutes the more valuable training the student receives.[39]

Smith supplied a questionnaire which contained a preselected list of proposed objectives to be rated according to a scale ranging from "most important" or "an essential aim" to "incorrect, not an aim under any condition." This research was an attempt to classify the accepted objectives under the seven cardinal principles of secondary education. Considering a return of sixty-six percent to indicate the proposed objective to be generally accepted as such, Smith's findings were summarized as follows:

> (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 and to apply important principles; and of

---

[38] W. A. Noyes, Jr., "Training the Chemist--A Critical Survey," Chemistry Bulletin, 12 (1925) pp. 67-68.

[39] Smith, pp. 180-183.

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.[40]

The need for delineation of purposes of instruction in introductory college chemistry was recognized in 1941 by the Committee on the Improvement of Science Instruction for purposes of General Education, a special committee of the American Association for the Advancement of Science on the Improvement of Science Teaching in Colleges and Universities, when L. W. Taylor, chairman of the committee, advanced the following statement:

> A relatively small number of the students who enter the introductory course in college chemistry continue their study in more advanced courses. A larger group of students take the course in order to meet certain requirements and still another group take the course solely for its contribution to their general education. The assumption has usually been made that essentially the same type of introductory chemistry course meets the needs of these different groups of students. One of the questions of general concern which this committee believes should be studied may be phrased as follows: Does the conventional introductory college course in chemistry through its content and method of instruction make a larger contribution to the education of those students who do not continue the study of the subject than would be possible in a different type of course?[41]

A questionnaire was sent to approximately 500 colleges and universities to ascertain the purposes of instruction in introductory college chemistry courses designed for non-science majors. The survey findings gave sufficient evidence to suggest a separate introductory chemistry course for non-science majors. The survey findings also reflected the point of view that the majority of those professors who teach an introductory course designed for both science majors and non-science majors

---

[40]Ibid.

[41]L. W. Taylor, Chairman, et al., "Chemistry Instruction for Purposes of General Education," Journal of Chemical Education, 18, (1941) p. 11.

feel that this course is, in general, unsatisfactory for the non-specialized student. The respondents believed that this regular course could be significantly improved for the non-specialized student, but they also expressed the fear that modification of the regular course may lead to superficial results for the specializing student. Instructors felt that an additional general chemistry course should be offered, but not the type commonly known as a physical science survey.

B. Clifford Hendricks, University of Nebraska, in 1942, concurred with the findings of Taylor; but he voiced strong opposition to some of the objectives listed in the survey findings of Smith when he presented the following argument:

> Some time ago a set of objectives was compiled which was approved by a representative group of college teachers of chemistry. This approval was probably given in the hope that such objectives, when achieved, would lead to successful work on the parts of students in subsequent courses.
>
> Such an assumption, that success in one course is indicated by a good record in a subsequent one, is erroneous in two particulars. It overlooks the fact that probably more than fifty percent of those students in service courses will never take any more chemistry and second, it assumes the doubtful inference that the greatest good to this group of students comes from remembering and understanding the technical intricacies of general chemistry. It is with this second assumption that professional schools take issue.[42]

This controversy was further extended by Hendricks' assertion that professional schools are really quite serious in their endeavor to have chemistry taught their students which will contribute to professional success rather than to high attainment in pure chemistry. Among the inferences of the preceding comments, the present investigator detected the

---

[42]B. Clifford Hendricks, University of Nebraska, "The Varied Objectives in Service Courses in General Chemistry," Journal of Chemical Education, 19 (1942) pp. 265-266.

Hendricks notion that one introductory college chemistry course was not sufficient.

A subjective but comprehensive description of the objectives of general chemistry and an indirect suggestive implication of agreement with Hendricks was vividly voiced by Hubert N. Alyea, Princeton University:

> We are chemists by profession because we are experimentalists by nature, and because some years ago we were students, our chemistry teachers wisely encouraged us in experimental research and we liked it.
>
> It is our duty, in turn, to imbue the next generation of young men with the understanding and spirit of research; and that, I believe, is the prime function of the general chemistry course.[43]

Alyea characterized research as being composed of three integral parts: (1) curiosity (2) fact finding and the acquisition of knowledge and (3) critical judgment. In summation, Alyea explained the function of introductory college chemistry:

> The relative emphasis on these three items depends naturally upon the particular course and its relation to the subsequent programs of the student. By electing the advanced general chemistry courses, the student has already indicated his scientific bent and his stimulated curiosity so that a fundamental training in advanced inorganic chemistry and the exercising of sound judgment is prescribed. On the other hand, for the beginner who will probably not continue in chemistry, curiosity and judgment are paramount, while knowledge is merely of transient importance.[44]

C. S. Adams, Antioch College, 1943, in reviewing the literature of laboratory objectives, developed a reservation regarding lack of research by college professors in regard to laboratory objectives and pedagogical practices. He showed that out of fifty literature references related to

---

[43]Hubert N. Alyea, "The Function of General Chemistry," Journal of Chemical Education, 18 (1942) pp. 309-310.

[44]Ibid., p. 310.

methods of laboratory instruction, covering a period of over thirty years, only five were applied to college classes.[45] The results of Adams' questionnaire and a similar study by Leonard F. Sheerer indicated the acceptance of the following as the objectives of general college chemistry laboratory work:

(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 or record and write a satisfactory report,
(d) develop the attitude of drawing conclusions only from observable or acceptable data,
(e) develop the habits of accuracy, honesty, self-reliance, cleanliness, and orderliness in laboratory,
(f) satisfy the student's curiosity and provide experience to develop latent interests,
(g) provide opportunity for instruction.[46]

The results of Adams' questionnaire gave ample truth that the teachers of general college chemistry were interested in new and improved testing devices, particularly as these related to laboratory achievement. Adams succinctly stated the status of the laboratory objectives in 1943 when he wrote:

> Very little progress has been made in developing adequate devices for measuring the achievement of the accepted objectives of laboratory work in general chemistry, other than the acquisition of knowledge. The paper-and-pencil measures of chemistry laboratory achievement that have thus far been devised fail to show consistent or marked differences among the several methods of laboratory instruction.

Performance tests, such as those reported by E. O. Smith and

---

[45]C. S. Adams, "The Importance of Laboratory Work in General Chemistry at the College Level," Journal of Chemical Education, 20 (1943) pp. 266-270.

[46]Leonard F. Sheerer, in Adams, "The Importance of Laboratory Work in General Chemistry at the College Level," Journal of Chemical Education, 20 (1943) p. 266.

> his staff, have produced encouraging results in measuring some of the laboratory objectives. Other studies are needed, particularly on the part of larger colleges and universities, in order to obtain statistically significant results so important in investigations of this kind.[47]

A survey of the literature since 1943 shows only a few articles directed toward objectives and/or evaluation. The collective and annual indices of the Journal of Chemical Education, with few exceptions, has deleted the references and cross references to objectives, namely the words objectives, aims, and collateral values. Nevertheless, many individuals, in discussing their respective chemistry curricula, have emphasized the need for both local and nationwide objectives. Jay A. Young reinforced Adams' request by offering constructive assistance when he formulated a new set of laboratory objectives.[48] Young is of the opinion that the laboratory objectives currently found in the prefaces of many lab manuals are of limited value. The criteria offered by Young, in reality, are modifications of the old objectives stated in behavioral terms in such a manner as to enhance and sharpen thinking. His opinions of the purposes of the laboratory and the ensuing criterion is not unlike the behavioral objectives of Montaque and Butts.[49] Indirectly, L. K. Nash[50] and the Advisory Council on College Chemistry[51] have implied the need for objectives and methods of evaluation in their criteria for inclusion of a

---

[47]Ibid., p. 269.

[48]Jay A. Young, "The Educational Use of Data--Challenge in the Laboratory," Journal of Chemical Education, 41 (1966) pp. 120-123.

[49]Montaque and Butts, pp. 33-35.

[50]L. K. Nash, "Boundary Conditions," Journal of Chemical Education, 41 (1964) p. 368.

[51]Haenisch, pp. 2-3.

topic in introductory college chemistry.[52]

At present, there are almost as many sets of objectives as there are chemists interested in the freshman course;[53] however, several objectives, both for science and non-science majors keep appearing in various forms. They are:

(1) Enthusiasm and interest in chemistry as an experimental science should be aroused by making the work intellectually stimulating and allowing the student to enjoy the laboratory experience within the limits imposed by safety considerations.
(2) The student should realize the nature of chemistry as an experimental science, concerned with trying to describe accurately what is happening when changes occur and then explain how and why these changes take place.
(3) There should be a maximum development in each student of his powers of observation and reason. He should understand and feel he is a part of the procedure of observation, generalization, and verification.
(4) The chemistry major, in particular, should acquire knowledge of certain techniques and manual facility in handling some scientific instruments.
(5) The laboratory should illustrate and reinforce the lecture.[54]

A few moments of deliberation give one the feeling that he is in a time machine which is operating in reverse. These objectives appear to be the reworded phrases of Adams and Sheerer.[55] The inherent problem, therefore, does not appear to be a statement of purposes but a development of teaching procedures to meet these goals.

The Content of Introductory College Chemistry

Apparently, the forces that were responsible for the unanimity of

---

[52]Ibid., p. 18.

[53]Ibid., p. 18.

[54]Ibid.

[55]Adams, pp. 266-270.

opinion regarding introductory college chemistry course objectives during the period 1918-1943 also contributed to a parallel controversy in regard to course content and the choice and sequence of topics. Although, in 1941, there was more or less consensus regarding topics to be covered in a first-year college chemistry course, the sequence of topics was a problem which required some thought before a definite plan could be formulated. Valuable assistance was offered by Joseph A. Babor, College of the City of New York, in 1942, when he listed the following selection guidelines to a choice of topics for inclusion in a general chemistry course:

> (1) What is the objective of the course in general chemistry in a particular college?
> (2) Another consideration which should influence the choice and sequence of topics is the previous preparation of the student.
> (3) The course may be designed to meet the requirements of two groups of students: those who intend to go on in chemistry and those who do not.[56]

Babor felt that a course based on criteria (2) above must be organized in such a manner that the choice and sequence of topics will provide basic principles, applications and sufficient theory to satisfy a chemistry major and not too much to discourage the art student.

Horace G. Deming, in 1948, issued a challenge to fellow educators by suggesting a pedagogical maneuver to challenge the voluminous increase in content and the resulting increase in size of textbook by remarking:

> It is better to treat a few topics in such a manner that students learn to think rather than range over many topics in a superficial way. ... So the way to future progress seems to lie in more thought on the part of college instructors

---

[56]Joseph A. Babor, "The Sequence of Topics in General Chemistry," Journal of Chemical Education, 19 (1940) pp. 263-264.

about goals and purposes.[57]

In reinforcing the views of Deming and also in answering the question, "What shall we leave out of general chemistry courses?" J. A. Shotton advocated a negative approach to the topic selection criteria of Babor and gave the following conclusions which were the results of a general chemistry workshop:

> No general agreement was reached, but the following criteria to aid a teacher in deciding what he should leave out were evolved:
> (1) can the ideas be taught and learned?
> (2) are we teaching content or methods of chemistry?
> (3) are they needed to keep the course accredited?
> (4) are they needed as professional training?
> (5) are they of local importance?
> (6) are they needed for everyday living?[58]

The workshop showed that the controversy is further exemplified by the other problems of general chemistry. These were and still are (1) why is it difficult to obtain agreement on what is fundamental? (2) how many general chemistry courses must we teach? (3) do students have difficulty with the concept of chemistry because of difficulty with arithmetic, or not being able to derive the correct mental picture? Implicitly permeating the statements of goals and objectives of the post World War II era is the demand for critical thinking. Deming and Shotton were of the opinion that the general objective of chemistry is to encourage the student to think critically.

---

[57]Horace G. Deming, "Guinea Pigs in the Classroom," Journal of Chemical Education, 25 (1948) pp. 445-449.

[58]J. A. Shotton, "A General Chemistry Workshop," Journal of Chemical Education, 27 (1950) pp. 619-621.

Admitting conjecture in part, Karol J. Mysels and Charles S. Copeland,[59] University of South Carolina, surmised that the overall content of a beginning course in college chemistry is rather well defined by the required or traditional curriculum and generally accepted as such; the point of contention being that the point of view of the instructor is reflected in the sequence in which topics are presented and the approach that is used in the topic presentation. These authors were of the opinion that this is an inherent pedagogical weakness which could be strengthened by a careful selection of sequence of topics. Their criteria for inclusion of a topic in freshman chemistry, different in point of view from that of Babor, was offered partitively:

> The ultimate goal would be for the student not to depend upon the instructor's work except for a limited number of statements of fact. To approach this goal it is necessary to proceed from the simple and familiar to the more complicated and less familiar. This tends to give the student a continuous grasp of the material and allows him to follow the reasoning better at each step. There is also a general extension of the range of phenomena directly observable by means within the students grasp. In other words, a good basis should be firmly laid at each point before proceeding to the next. Finally, we feel that related phenomena should be grouped together, both for ease of learning and as an illustration of the generality of the principle involved.[60]

Philip J. Elving offered a somewhat different view than that of Babor and Mysels, when he expressed the opinion that the order in which descriptive topics are introduced varies greatly and is perhaps immaterial so long as some logical pattern is followed. Elving also felt that the amount of time that is devoted to the various descriptive topics should

---

[59]Karol J. Mysels and Charles S. Copeland, "The Sequence of Topics in a Beginners' Course," Journal of Chemical Education, 28 (1951) pp. 163-167.

[60]Ibid., p. 167.

be an individual professor choice which is directly dependent upon teacher and student interest.[61]

John E. Cavelti,[62] Allegheny College, in 1943, supported a somewhat different approach than previous writers when he not only discussed the selection of content but gave specific examples to support his suggestions. Cavelti was convinced that the first need is a careful consideration of the content of the courses in the chemistry curriculum, correlated with a view to simplification, with an emphasis on fundamentals in each course, and a real integration of courses so that the graduate will not only be familiar with developments in all important fields, but will also be confidently grounded in the fundamentals of science. Cavelti advocated a structural method for selecting course content by stating the following points:

> Decisions as to the proper content of an elementary course are always difficult, and especially so in smaller institutions, where, of necessity, students with different aims must be taught together. Obviously, those things must be included which the student who will take no further courses in chemistry may reasonably be expected to need to know. For this reason the modern tendency to include a sketch of organic chemistry seems thoroughly desirable, although in courses intended specifically for chemistry majors it might well be omitted. For these students the real aim of the course should, it seems to me, be such a grounding in the fundamental theories and facts that the resulting knowledge can be relied upon to be there when we wish to build upon it in more advanced courses. I think most of us will agree that the basis of the course should be an exposition of the facts of the atomic structure, rather than of the methods by which they were obtained, and the application of these facts, through the periodic system, to the chemical behavior of elements and compounds. We are fortunate, in chemistry, to

---

[61]Philip J. Elving, "The Curriculum in Chemistry," Journal of Chemical Education, 29 (1952) p. 219.

[62]John E. Cavelti, "The Perennial Problem of Course Content in a Growing Science," Journal of Chemical Education, 20 (1943) pp. 271-273.

> have so powerful a coordinating mechanism. In this regard the newer developments have simplified our task rather than complicated it.[63]

Cavelti, without any corresponding agreement as to topics which may be omitted, suggested the following content topics, which seem to be in contrast to the above quotation, tantamount to achieving his previously stated objectives: (1) the balancing of oxidation-reduction equations, except in the case of the simplest direct electron-transfer types; (2) complicated examples of chemical equilibria, solubility products, and the like; (3) calculations involving the normality concept; (4) all except brief reference, with no expectation of retention, to such topics as the application of X-rays to the determination of crystal structures, radioactive degradation series, methods of determining molecular weights (except direct applications of Avogadro's law, and perhaps freezing point depression), colloid chemistry, the meaning of electrode potentials, etc.

Cavelti surmised that there is a need for an elementary course which is _elementary_, but intense, and which stresses descriptive inorganic chemistry to a greater extent than is now customary. Norman Davidson projected another criteria for inclusion and selection of content for the introductory college chemistry course.[64] Davidson advocated lectures on special topics where one can illustrate the utility of structural considerations in explaining the properties of substances. To Davidson, the important thing is not just what or how many facts we teach, but that we stimulate our students to have a healthy interest in facts. He believes

---

[63]Ibid., p. 272.

[64]Norman Davidson, "Theoretical Chemistry and Descriptive Chemistry in the General Chemistry Course," _Journal of Chemical Education_, _27_, (1950) pp. 445-447.

that this objective, the intelligent use of facts, could be effectively achieved by subjecting the student to an extensive study of selected topics in descriptive chemistry, correlated by constant references to actual experimental material and interpreted temporally with theoretical material. In summary, Davidson remarked:

> Then, I think that in spite of an ever-increasing amount of factual information, chemistry is not becoming more and more fragmented. It is becoming more and more integrated and unified by general theories and by general methods of investigation which are applicable to a variety of fields... To participate in this synthesis, the student must have training in both descriptive and theoretical chemistry, and I believe there will be greater emphasis on the correlation of descriptive and theoretical topics.[65]

Arnold J. Currier, Pennsylvania State University, in 1955, discussed a difficult problem in the teaching of general chemistry which resulted from the dual viewpoint in connection with the use of a textbook correlated with the laboratory manual.[66] His personal preference is to place more emphasis upon the textbook material. In defense of his stated preference for textbook material, Currier explains:

> In all too many cases, the student gets the impression that the experimental work is largely a matter of illustration or confirmation of the material presented in the textbook. To a large degree this aspect of the laboratory work may be a desirable one, but the thoughtful and perhaps less ambitious student can rightfully say, "What's the use of doing the experimental work when we know the answers because they are all in the book?" Some of the laboratory manuals of the workbook type which include exercises involving the tabulation of facts or data from the textbooks may be especially conducive to this point of view.
>
> To correct this undesirable tendency or practice, some writers have prepared texts which make the individual experimental

---

[65]Ibid., p. 447.

[66]Arnold J. Currier, "Trends in Chemical Education," Journal of Chemical Education, 37, (1955) pp. 286-289.

work the focal point of the course.[67]

In 1958, Laurence E. Strong and O. Theodore Benfey gave a conflicting view to that of Davidson regarding the surfeit of knowledge when they discerned the trend regarding chemical concepts at the freshman level by inferring:

> It is clear to the authors that there is a rife among chemistry teachers, a great amount of dissatisfaction with the present chemistry curriculum. On the other hand there has been, to our knowledge, very little experimentation with major aspects of the teaching plan.
>
> The Brown curriculum is a notable exception achieving remarkable success by dropping general chemistry and making essentially a simple rearrangement of the present courses, with organic chemistry as the freshman course.[68]

The Journal of Chemical Education described some thirty or more curriculum developments during the period 1957-1963.[69,70,71] Bennett R. Williford, Jr., at the Bucknell conference, Bucknell, Pennsylvania, reinforced the initial statement by Strong and Benfey and disagreed with the last statement when he reiterated the status of the content of introductory college chemistry vividly and succinctly, by concluding:

> There was no general agreement as to what constitutes the best freshman course. The majority favored a modernized course but few schools now find it best to begin with organic chemistry or an integrated-physics.[72]

---

[67] Ibid., p. 289.

[68] Laurence E. Strong and O. Theodore Benfey, "Chemical Concepts and the Chemistry Curriculum," Journal of Chemical Education, 35 (1958) p. 164.

[69] Bennett R. Williford, Jr., "The Undergraduate Training of Chemistry Majors," Journal of Chemical Education, 38 (1961) p. 251.

[70] Stephen E. Wiberly and Herbert H. Richtol, "A New Freshman Chemistry Program," Journal of Chemical Education, 41 (1964) p. 147.

[71] Walter, p. 524.

[72] Williford, p. 251.

Dating from the Brown experiment in 1958, the Journal of Chemical Education[73,74,75] and the Advisory Council on College Chemistry (AC_3)[76,77] have either summarized or published numerous articles on introductory college chemistry courses which were designed for individual colleges and universities. These descriptions vary from independent study courses, to new laboratory courses, on to physics-chemistry combinations. The content ranges from a low level of difficulty to that which necessitates a good background in calculus for comprehension. The many forces or factors which are causing reconsideration of the content of the first college chemistry courses are well known.[78,79] One of the causes behind the revolution is the vast amount of chemical information and new theories that has been created in the past decade; hence, the new innovations in the first-year college chemistry courses contain new content. The literature survey shows some other modification agents, in general, to be: (1) freshman students are better prepared; (2) a wider variety of students, with diverse goals, abilities and backgrounds require closer consideration of specific needs of selected groups of students; (3) the flood of new information requires careful consideration of which topics are to be included

---

[73]Journal of Chemical Education, 35 (1958) p. 164 ff., pp. 168-173.

[74]"Recent Trends in Undergraduate Chemistry Curricula," pp. 126-147.

[75]Journal of Chemical Education, 42 (1965) pp. 524-528.

[76]"Experimental Curricula in Chemistry."

[77]Haenisch, p. 5.

[78]L. Carroll King, in "Recent Trends in Undergraduate Chemistry Curricula," Journal of Chemical Education, 41 (1964) p. 126.

[79]Haenisch, p. 3.

in a course; (4) modern equipment makes available challenging new experiments for freshman laboratory as well as methods of presentation; and (5) availability of undergraduate grants from several federal agencies. Stephen E. Wiberly and Herbert H. Richtol, in 1964, were in agreement with the above factors that have caused changes in first-year chemistry curricula and, in addition, added a few when they gave the following reflection:

> Recent improvements in the teaching of high school chemistry and the advent of general chemistry texts with a change in emphasis plus the availability of undergraduate grants from the National Science Foundation have brought changes in many first-year college chemistry courses.[80]

Individual professors, aware of the curriculum changes, began to call for assistance. Robert I. Walter, in discussing the survey report on the changing curriculum in chemistry, asked cooperation of his colleagues in the task of keeping a periodic check on evolving curricula by stating:

> It seems clear that exchange of information on changes in the curriculum are of value to schools which plan (or have already made) such changes. The experiences of others form a useful basis for one's own plans.[81]

Laurence Strong extended Walter's plea for cooperation by suggesting that interest should be initiated at the beginning level in college chemistry. Strong's statement testifies to the scope and influence of the content revolution at the college level when he stated: "If chemistry teaching is to become more effective, we need reorganized texts and courses."[82]

---

[80] Wiberly and Richtol, p. 147.

[81] Walter, p. 524.

[82] Strong, p. 128.

In view of the need to stimulate improved college chemistry teaching, the Advisory Council on College Chemistry (AC_3)[83] (an independent group of professors operating under a National Science Foundation Grant in an advisory capacity) appointed a Committee on General Chemistry in 1963. AC_3 came into being as a result of an ad-hoc committee convened in October, 1961. This group was asked to consider the improvement of college chemistry teaching, especially in view of the Chemistry An Experimental Science Study (CHEMS) and Chemical Bond Approach (CBA) programs at the secondary level and the great changes in the allied fields of biology, mathematics, and physics.

According to AC_3,[84] the content of the first-year chemistry courses in colleges and universities in the United States is generally determined by the available textbooks. AC_3 panel members concur that the principal way to improve the topics in college chemistry is to improve the textbooks and other teaching materials.

From the emphasis on content in terms of selected topics, chemistry professors are subsequently faced with delineating a core of topics. The concomitant activities and changes in introductory chemistry curricula have been labeled by King as "change."[85] J. A. Young's statement testifies to the scope and influence of the revolution (objective appraisal of the post World War II to 1964 period):

It is well known that the selected topics being taught in

---

[83]"Advisory Council on Chemistry Set Up," Chemical and Engineering News, 41, January 14, 1963, pp. 43-44. Hereafter, the Advisory Council on College Chemistry will be designated as AC_3.

[84]L. Carroll King, "Modern Texts are Needed to Upgrade College Chemistry Courses; Freshmen Often Ready for Quantum Chemistry, Thermodynamics," Chemical and Engineering News, 42, February 14, 1964, pp. 42-44.

[85]King, in "Recent Trends in Undergraduate College Chemistry," p. 126.

> introductory chemistry have changed during the past several years, particularly since 1946, but the usual sources of information concerning the details have been casually by word of mouth or informal conversations.[86]

AC_3 reinforced and confirmed the view of Young when the Committee on General Chemistry remarked:

> There is considerable interest in delineating the hard core of topics presently being taught in introductory college chemistry. Many institutions are questioning the place of the first course within the total chemistry curriculum. The extent of adoption of new topics into introductory chemistry has not been known, although it is well known that there has been considerable change in course content in recent years. Teachers in junior colleges are particularly interested in knowing the main topics presented in introductory courses as taught in universities and four-year colleges. Currently, 25% of all undergraduates are studying in junior colleges, and many of these students later transfer to universities and four-year colleges. Core topics must be identified and taught to this large group of students if the transfer students are not to be put at a great disadvantage.[87]

Two surveys have been made heretofore to determine what topics have been taught and which are excluded in the first-year course. H. J. Nechamkin, in 1961, furnished a preselected list of topics to be rated according to a scale ranging from "essential for inclusion" to "unnecessary and should be omitted" in a questionnaire to which approximately 100 respondents replied.[88] A less subjective source of information on the content topics presently being taught in first-year college chemistry was undertaken by Jay A. Young.[89] The survey was sponsored by AC_3, and letters

---

[86]Young, "The Content of the First Course in College Chemistry," p. 47.

[87]Haenisch, p. 5.

[88]King, in "Recent Trends in Undergraduate College Chemistry," p. 126.

[89]Young, "The Content of the First Course in College Chemistry," p. 477.

were sent to 100 randomly selected colleges, universities, and junior colleges requesting copies of the final examinations in the first-year chemistry courses for the academic year 1962-63. The primary purpose of the study was to find what topics are normally included in a general chemistry course, what changes are needed, and to stimulate improvement; that is, to provide useful information from which a sound basis for individually determined improvements could be established. A total of 52 institutions contributed final examinations for this study. Young observed that the general pattern of final examination topics closely followed the pattern of topics found in available texts and, in conclusion, exclaimed: "It is, therefore, imperative that the very best efforts be expended in the preparation of general chemistry texts."[90]

The present era is characterized by the need to give fresh consideration to the introductory course. In response to this need, the General Chemistry Committee of the Advisory Council on College Chemistry convened at Tulane University, February, 1964. No attempt was made to outline a single introductory course; rather a consideration was given to a number of specific topics and specific methods of instruction which might be appropriate for freshman chemistry.

Based primarily on an outline presented by L. K. Nash of Harvard University, the following "Boundary Conditions" were offered as criteria for selecting topics in first-year chemistry:

1. The topic should be capable of natural integration into previous knowledge of the student and should add to his intellectual score.
2. The topic should be appropriate to the future activities

---

[90]Ibid., p. 478.

of the student.
3. The topic and its mode of presentation should stimulate the student to take upon himself the arduous lifetime task of maximum intellectual development.
4. The first course being an introductory one, it should convey something of the nature of science.
5. The topic should be capable of honest presentation at the introductory level, with minimal extracting of rabbits from a hat or requiring the student's passive acceptance of our dogmatic assertions.
6. The topic should equip the student to solve recognizably worthwhile problems.
7. The topic should be illustrable by student laboratory experiments and lecture demonstrations.
8. The topic should be highly relevant to other subjects treated in the introductory course.
9. The topic should either be a hard-core topic for introduction into the ways of chemistry, or it should not preclude the acquisition of these fundamental topics during the first-year course.[91]

The following statement was prepared with the help of all participants and represents the areas of general agreement among the participants on the topics of interest to this conference:

> The participants in this conference recognize that it is not possible to describe or develop a single first-year college chemistry program to meet the needs of all colleges and universities. Rather we believe that the strongest and most effective programs are developed by enthusiastic and dedicated teachers who take into consideration the local needs, the institutional goals and admission standards as well as national trends and creative developments in chemical education. In addition we recognize that although the quality of high school training is variable, there is a general improvement in the quality of the background of students enrolling in first-year college chemistry courses, due to the improved high school courses now available. We believe that the strongest force behind the changes now taking place in college chemistry courses is the desire to emphasize the nature of the knowledge-obtaining enterprises of the chemist and to take the student to the edge of research.[92]

The Conference recommended:

---

[91]"Editorially Speaking," p. 113.

[92]Haenisch, p. 20.

(1) Efforts be made to stimulate preparation of a series of outlines and suggestions for teaching (at the first-year college chemistry level) some important topics not adequately treated in current texts.
(2) A study be made to ascertain which additional topics traditionally treated in higher-level courses can be successfully presented in first-year college chemistry--and if such topics are treated at this level, to what extent they must be presented again.
(3) Although the entire first-year course can't be taught as rigorously as many higher-level courses, a large part of any first-year course can be presented this way.
(4) A comprehensive effort be made to continue to revitalize the laboratory work in first-year college chemistry. This can be done by uncovering and publishing new kinds of experiments and ideas.
(5) Qualitative analysis be critically re-examined to see if the principles demonstrated in this work can be presented more efficiently.
(6) The use of individually prepared research-type reports patterned after a research notebook be encouraged.
(7) Where special programs for high-ability students are available, they should be provided throughout the students' college career.
(8) An optimum ratio of students to instructors be provided to give quality instruction in the laboratory. Reasonable ratios now seem to range from 10 to 16 students per instructor.
(9) Coordination between chemistry teachers and those in the other sciences be increased with a view toward reducing duplication and increasing the transfer of useful principles and information.
(10) The term "general" chemistry be discontinued and a more descriptive term be used.[93]

Nelson McKain, Jr., took opposition to the Tulane panel recommendations. The rebuttal is as follows:

> The report of the Advisory Council on College Chemistry is disturbing. The article did not state the objectives of the proposed course, not its entire content, nor the students for whom it is primarily intended. But what was said creates considerable doubt that the committee is thinking of a chemistry course for ordinary college freshmen.
>
> Reading between the lines, it seems the committee does not favor a well rounded, informative, albeit rigorous, course

---

[93] L. King, "Modern Texts are Needed to Update College Chemistry Courses; Freshman Often Ready for Quantum Chemistry, Thermodynamics," p. 44.

in general chemistry, but prefers a specialized offering primarily intended to groom the freshman for graduate school. The statement that "undergraduates can begin research at the freshman level" applies to only a small percentage of any ordinary freshman class. What shall be done with the others? Will a "core" consisting of thermodynamics, the Schrodinger wave equation, and speculations on the hydrogen-oxygen bond meet the needs of students planning careers in medicine, biology, and other fields? Will such a course be suitable for the increasing number of students who take freshman chemistry as a general education course with no intention of pursuing the subject beyond the freshman year? Many good students do not enter college with a background of high school calculus, nor even a sound foundation in chemistry and physics. Can these students be given a meaningful treatment of thermodynamics in a reasonably short time? Or would it not be better to cover the more conventional topics thoroughly, thus laying a foundation for their future work in science? Then, as time permitted, the more advanced concepts might be introduced on a selected basis, not as a "theme" of the course. Certainly the idea of spending more than a quarter of a semester on such a specialized topic as the bonding of hydroxyl is of dubious merit in a beginning course.

It has taken our educational system more than a decade to outgrow "progressive education" and its effects still linger in places. Is the style swinging to the opposite extreme, rigor for rigor's sake? Is freshman chemistry to be made so tough that only the graduate of a two-year high school honor program can enroll? And is its content to be made useful only in meeting the requirements of a Ph.D. degree? The broadly based, informative course in general chemistry, such as is covered in many of the newer texts, meets the needs of the average college student very well, and if properly presented, will provide a challenge to the best of them. If a specialized, highly technical course is desired for a few specially selected chemistry majors, there can be no objection to its being offered. But such a course merely trains, whereas the broader course educates. The broader course provides the background of information and experiences in problem-solving needed by a variety of students in fields other than chemistry. Such a course, competently taught can be made challenging and also interesting. The students who select chemistry as a career are probably influenced more strongly by a good teacher than by course content.[94]

---

[94]McKain, p. 4.

The previous discussions[95,96,97,98] show a diversity of approaches to the teaching of first-year college chemistry. Young's survey[99] and the AC_3 panel suggestions[100] reinforce this diversity by showing that the current available textbooks generally determine the content and outline of the first-year chemistry course. The investigator is of the opinion that a diversity of approaches to the teaching of first-year college chemistry is pedagogically sound. The sequence in which the topics are presented and the approach that is used in the topic presentation, however, often lead to a pedagogical weakness--the lack of a conceptual framework to show how concepts are developed and related. The principle problems are coordination, distribution of topics, and arrangement of course content units in a logical and coherent sequence.

The selection guidelines for inclusion of a topic in an introductory college chemistry course were formulated by Babor,[101] Shotton,[102] Mysels[103] and Nash.[104] These discussions show that the basis for a logical arrangement of topics in freshman chemistry rather than an adherence to

---

[95]Currier, pp. 286-289.

[96]Strong and Benfey, p. 164.

[97]Williford, p. 251.

[98]Wiberly and Richtol, p. 147.

[99]Young, "The Content of the First Course in College Chemistry," p. 477.

[100]"Advisory Council on Chemistry Set-Up," pp. 43-44.

[101]Babor, pp. 263-264.

[102]Shotton, pp. 619-621.

[103]Mysels and Copeland, pp. 163-167.

[104]Nash, p. 368.

traditional sequence has been advocated for at least three decades. This need is also reflected by the extensive revisions and experimental innovations in the first-year chemistry course, such as the introduction of substantial amounts of physical principles, bonding theory, organic chemistry, and quantitative analytical techniques in the laboratory. AC_3 has urged that information about experimental curricula and a summary of the discussion and conclusion be made generally available. The suggestion has merit but is inadequate. The previous data and opinions give ample evidence that an analysis of the general chemistry course to identify basic unifying concepts that may allow a systemization which can provide greater efficiency and effectiveness in teaching is needed. A consolidation of the ideas of the writers mentioned in this section on content is merited--the ensuing result being a logical, systematic procedure for the inclusion of a topic in the introductory college chemistry course, a logical arrangement of topics, a logical development of concepts to teach the processes of chemistry, and a respect for and interest in facts. The discussion by AC_3 panel members[105] supports the investigator's position. One solution to the controversy regarding selection of specific topics and methods of instruction would be a federal supported project that would bring together professors of chemistry from all classifications of colleges and universities with an ensuing purpose of designing introductory college chemistry courses with a concomitant analysis of the structure of the introductory course and a study of the process of teaching first-year college chemistry. Since the previous discussions have shown the textbook to be authority in regard to introductory college chemistry courses, the

[105]Haenisch, p. 17.

implication is a need for consolidation of experiences, not diversification of practices.

The General Chemistry Laboratory

There is a great deal of dissatisfaction with the present operation of freshman chemistry laboratories. Suggested solutions range from doing away with freshman laboratory to making the laboratory the center for the first-year course.[106] The present situation is comparable to the Demonstration Versus Laboratory controversy of the 1920-1940 era.[107]

Study of the foregoing research and opinion reflects the dissatisfaction with the teaching practices in freshman chemistry laboratory for the past 75 years and creates implications as well as questions. C. S. Adams,[108] Antioch College, in reviewing the literature of laboratory objectives of general chemistry developed a reservation regarding the tendency to consider one laboratory method superior to another. In 1942, he sent out a questionnaire to some 175 universities requesting a rating of some proposed objectives in general chemistry laboratory work. One hundred forty of these questionnaires from 140 institutions were returned. The purpose of the survey was to re-examine the general chemistry laboratory program with respect to objectives, methods, course content, methods of appraisal. Adams reported that the literature up to 1942 had recorded

---

[106]Haenisch, p. 17.

[107]Saul B. Arenson, in "Demonstration Versus Laboratory Once Again," Journal of Chemical Education, 15 (1938) p. 592.

[108]Adams, pp. 267-268.

only two investigations, those of R. E. Horton[109] and E. O. Smith[110] which had specifically attempted to measure the outcomes, achievements and effectiveness of laboratory methods by _actual_ _performance_ _tests_. Adams reported that previous investigators had used paper-and-pencil tests, which he believed, in probability, do not measure motor skills, manipulative ability, laboratory technique, and tangible acceptance with materials. In order to defend his position, Adams summarized the final conclusions of the two-year investigation by Horton and Smith:

1. The customary method of measuring achievement in elementary chemistry by paper-and-pencil tests measures chiefly the outcome of but one of the major objectives of laboratory work; viz., the acquisition of information.
2. Such paper-and-pencil measures of achievement in chemistry fail to show any consistent or marked advantage for any of the three methods of laboratory procedure studied; viz., the individual, the lecture-demonstration, and the lecture method.
3. At the conclusion of a laboratory course in beginning chemistry those pupils who have had individual instruction do consistently better than those who have seen the experiments performed for them in class or those who have heard the instructor explain the experiments in lecture, when these pupils are measured by a laboratory performance examination.
4. This difference in ability in favor of those who have had one semester of individual laboratory instruction over those who have had the other methods of instruction is not entirely erased at the end of the second semester.
5. Since the difference is slight it would appear that one semester of laboratory instruction by demonstration followed by a second semester of individual laboratory instruction accomplishes the same results as two semesters of individual laboratory instruction.
6. It seems probable that the best plan of laboratory procedure is to present some of the experiments, particularly during the first semester, by demonstration. The experiments involving the more complex apparatus, those in which

---

[109] R. E. Horton, "Does the Laboratory Belong?" _Journal of Chemical Education_, _5_ (1928) pp. 1432-1443.

[110] E. O. Smith, "Improvement of the Individual Laboratory Exercise in Chemistry," _Journal of Chemical Education_, _6_ (1929) pp. 1130-1135.

it is most difficult to obtain the correct results, and those which may have an element of danger involved, are believed to yield the best results to the classes as a whole by the lecture-demonstration method.

7. Contrary to the conclusions of many of the previous investigators the individual method of laboratory instruction is superior, particularly for the superior student, while the lecture-demonstration method may be somewhat better for students at the lower intelligence levels.
8. Further study is necessary to obtain better methods or devices to measure the student's attainment of the generally accepted aims and objectives of laboratory work.[111]

Adams felt that more pioneering work is needed in the area of performance tests and predicted that these tests will become part of the first-year chemistry laboratory program in the not too distant future.[112] The investigator believes that the need still exists today and little evidence indicates that such tests have materialized.

Other educators have also shown dissatisfaction with the freshman laboratory work. Robert K. Summerbell, Northwestern University, in 1954, severely criticized the standard laboratory experiment when he said:

> We chemistry teachers sometimes defend our routine laboratory work by saying that the student is being taught by "observation." Any experienced chemistry teacher can cite numerous examples parallel to those described. No student ever learned to make observations by doing routine experiments that simply confirm statements of the text or of the instructor.[113]

Summerbell advocated the use of unknowns to improve the introductory chemistry laboratory when he had this to say:

> We have found that by introducing unknowns the value of this experiment is greatly increased. There is no longer any problem of honesty. The student is asking a question of nature, and the only way he can arrive at an answer is to make observations. He does so, and a good result gives him a real

---

[111] Adams, pp. 267-268.

[112] Ibid., p. 268.

[113] Summerbell, p. 365.

thrill. He has experienced the excitement of experiment.[114] Summerbell concurred with Adams' plea for performance tests but, in addition, extended the evaluation problem to include not only performance but also motivation and offered the following solutions to assist professors of college chemistry:

> The evaluation of the effectiveness of teaching methods is one of the most difficult of educational problems, particularly when we are trying to measure such intangible things as student motivation. As scientists we demand measurements that can be expressed numerically. Because of the pioneering work of such a group as the Examinations Committee of the Division of Chemical Education, we know pretty well how to test efficiently such things as subject matter retention, ability to balance equations, or ability in working mathematical problems. Tests are even available for measuring competence in laboratory manipulations, or ability to apply scientific reasoning processes to a specific situation. All of these things are important and the proved validity of such tests is encouraging, but no satisfactory method of measuring motivation has come to my attention. Data can be collected as to the proportion of students electing advanced work in the field, but such data are subject to much random variation and hopelessly out of date by the time significant amounts have accumulated. There are, however, a number of less precise but perhaps more significant indications that are available. Do the students ask questions during, and more important, after the class? Are the students difficult to eject from the laboratory? Do they use library references and ask for more? Do they inquire about the possibility of a career in science? Do they attend unrequired public lectures in the field? Some of these criteria may be better than formalized tests as to the adequacy of the teaching. A fair portion of students who have been taught effectively should do all of these things.[115]

The general chemistry laboratory is a particularly vexing problem. Everyone agrees it should be significant and provide motivation, but the effective processes for accomplishing this have not yet been clearly defined.[116] The evidence is far from conclusive that educators really

---

[114]Ibid., p. 366.

[115]Ibid.

[116]Haenisch, p. 18.

realize the educational value of laboratory. Positive confirmation of this statement is reflected in the following report on the status of the chemistry laboratory:

> What to do with laboratory in undergraduate chemistry courses remains a complex, unsolved problem despite a resurging interest now evident on a national and local scale among teachers in small and in large colleges. As this year's intake of freshmen settles into a new environment, teachers are appraising the difficulties--conceptual and physical twixt lecture and laboratory.
>
> One of the difficulties in big universities is that there are too many undergraduates, particularly freshmen, to be accommodated in existing laboratories. Relatively expensive laboratory facilities and competent staff are usually necessary to make a laboratory course challenging to students. To "solve" the problem, a few universities have abandoned freshman laboratory altogether; other schools are likely to do so. Some teachers feel, however, that teaching chemistry--an experimental science--without laboratory is analogous to training an artist without providing him paints and brushes.
>
> While the problem remains unsolved, there are many chemistry teachers working on it. Several are experimenting with ideas to break the boundaries between the traditional subdisciplines of chemistry. One way to break these boundaries is to teach unified undergraduate laboratory courses--for example, combining physical, inorganic, and analytical; biochemistry, organic, and analytical; and organic, inorganic synthesis. Some combinations are in operation.
>
> Although there is considerable interest in unified laboratories, there is little readily available information about what is being done and why. Nor is there much direct contact between different individuals or groups working along the same or similar lines. The Advisory Council on College Chemistry is trying to stimulate exchange of ideas among teachers and to disseminate information on the topic.[117]

The objectives of the introductory college chemistry laboratory were vividly and succinctly stated in the previous discussion by Adams.[118]

---

[117]David N. Hume, "Teachers Try to Unify Laboratory Courses," Chemical and Engineering News, 45, November 20, 1967, pp. 53-54.

[118]Hammond, p. 48.

The placing of Adams' objectives in juxtaposition with the objectives of Richards[119] show that the statement of goals for the first-year college chemistry laboratory have changed little, if any, the past forty years. The pressing need appears to be a choice of experiences to meet these stated objectives and the ensuing evaluation methods. The AC_3 publications and the Journal of Chemical Education publications[120] show the dissemination of many laboratory experiments at the introductory college chemistry level. The investigator believes the solution to the problem appears to be a consolidation and/or modification of content rather than a dissemination and exchange of ideas. The investigator believes that first-year chemistry students should receive experiences in designing open-end experiments, collecting and recording data, formulating and verifying hypotheses, drawing generalizations from data, and designing write-ups. The student should be given directed-discovery experiences that allow him to discover new facts and to give him a respect for facts and corresponding practice in the use of data and facts. Chemistry is an experimental science, and the laboratory is an integral part and is the proper educational environment where students should learn chemistry by acting like chemists. The professors of chemistry might profit from an innovation somewhat like the Physical Science Course for Non-Science Students at Rensselaer Polytechnic Institute, New York. The suggestion of Summerbell in regard to the use of unknowns[121] might be the basis of a starting point.

---

[119]Richards, p. 54.

[120]Modern Experiments in Introductory College Chemistry, Stanford University, California, Advisory Council on College Chemistry, 1966.

[121]Summerbell, p. 365.

Suggested Solutions to Current Controversy

Accumulated information pertaining to the first-year course content has already reached such mammoth proportions that it is impossible to include everything of importance in a first-year chemistry course. As information and new ideas proliferate, college curricula seem to become more inadequate, despite continuous efforts to upgrade courses. Since courses can't grow without limit, incorporation of new material always demands deletion of some topics which have traditionally been considered indispensable to sound chemical education. One consequence of the changes within established courses is increasing incoherence in the program as a whole. Some subjects are treated in several courses, with little attempt at cross correlation while other important topics are neglected entirely.

Admitting conjecture, in part, George Hammond[122] of the California Institute of Technology claims the time is ripe for a change and suggests a complete overhaul for college chemistry curricula. He is not expecting ready acceptance of this proposal, although the Westheimer Report,[123] in essence, seems to agree with his approach. His pessimism is based upon his belief that chemists "have become highly conservative, an attitude that is inappropriate in any activity designed to produce new knowledge."[124]

Hammond's proposed freshman chemistry course, general chemistry, differs some from its current counterparts. According to Hammond, today's freshman college courses have included more and more physical chemistry

---

[122]George Hammond, "Proposal Revamps Chemistry Curriculum," Chemical and Engineering News, 44, November 14, 1966, p. 48.

[123]Frank H. Westheimer, "Chemistry: Opportunities and Needs," Chemical and Engineering News, 43, November 29, 1965, p. 93.

[124]Ibid., pp. 48-49.

with almost exclusive emphasis on structural concepts; and, although they are sophisticated and challenging, they are not "general chemistry." His proposed course in general chemistry would, hopefully, give the student a picture of the entire field of chemistry, the kinds of problems that it contains, and "various kinds of theory" used to attach problems.

The proposed general chemistry course begins,[125] much like present freshman courses and very similar to the views of Cavelti, with a discussion of elementary structural concepts--atoms, molecules, and chemical bonds, resulting in a discussion of properties of matter in condensed phases that helps introduce the student to thermodynamics. This train of thought leads to a discussion of chemical reactions, including stoichiometry problems and equilibrium. An exploration of the periodic table is guided by atomic theory and used to introduce the basic concepts of systematic inorganic chemistry. Near the end of the course, a brief discussion of synthetic chemistry makes the student aware of the field's existence, objectives and challenges.

Other educators are utilizing multidisciplinary (multiD) courses as the vehicle to give structure to the discipline of chemistry. Multidisciplinary courses, according to Edward C. Fuller,[126] Beloit College, Wisconsin, offered to science majors are increasing in number despite the extra

---

[125]Hammond's proposed freshman course differs some from its current counterparts. According to Hammond, other first-year courses include more and more physical chemistry with almost exclusive emphasis on structural concepts. His proposed course in general chemistry would, he hopes, give the student a picture of the entire field of chemistry, the kinds of problems that it contains, and "various kinds of theory" used to attack problems.

[126]Edward C. Fuller, "Scarce MultiD Courses Gain Ground," <u>Chemical and Engineering News</u>, <u>45</u>, September 18, 1967, pp. 66-67.

demands they make on the faculty and students. Aided by the Advisory Council on College Chemistry, Fuller distributed 1600 questionnaires to determine the incidence of multiD courses offered by schools to majors and nonmajors in science. Of the 1000 returned, 75 respondents stated that multiD courses are taught to science majors. Of those 75 responses, 64 were usable and indicated that almost half of that number of institutions offered one multiD course to nonscience majors and another to science majors.

The multiD courses have been divided into elementary and advanced classes. The elementary courses usually account for six to nine semester hours in each semester of the first year. Their contents may vary considerably from college to college. For example, the Claremont California Colleges (Claremont Men's College, Pitzer, and Scripps) offered a combined chemistry-physics course in the first semester of the freshman year, followed by concurrent semesters in chemistry and physics. Florida Presbyterian College, St. Petersburg, uses a four-semester course for science and nonscience majors that includes the main topics: mechanics, chemical energetics, macromolecules, and evolution. In describing the advantages of the multiD courses, Fuller says:

> Time saving and better learning may be achieved by closely relating aspects of one discipline with a course in another. For example, teachers at Beloit College cover only the physics arising from specific aspects of chemistry in the course. Particle dynamics, work and energy, temperature, and heat are taught to quantitate and coincide with gas kinetics and thermodynamics in chemistry. Similarly, nuclear physics and radioactivity coincide with nuclear chemistry.[127]

---

[127]Ibid., p. 67.

Some chemistry educators have responded to the plea of Robert I. Walter,[128] Haverford College, Pennsylvania, and the Advisory Council on College Chemistry[129] to offer novel suggestions in regard to introductory college chemistry laboratory. But not all agree how the student's instruction should tailor him for a place in research and industry. In answering the question, "Why have laboratory?" Charles Wilcox of Cornell University gave a comprehensive response that implied his philosophical, psychological, sociological, and pedagogical position as to the description of his concept of the present-day introductory chemistry laboratory:

> Chemistry teachers are designing new laboratory programs to counteract rapidly rising numbers of undergraduates and aging methods of laboratory instruction. Although the function of laboratory instruction should be to teach students execution and design of experiments, traditional teaching and swelling ranks of students may force the use of canned experiments whose quality is only slightly above matching blanks with predetermined answers.
>
> What's needed to reconcile student numbers with individual and meaningful instruction is a program of experimental units linked to a central theme. Such a program would be a central trunk of guided, thoroughly developed, sequential work and from this trunk several branches would provide varying degrees of detail. All students would do the work along the trunk; each would make his choice of the branch to follow.[130]

In its nascent form, the program's design considers fundamental approaches to preparing and purifying materials, determining compositions, and designing experiments for measuring physical and chemical properties. In terms of experiments, the program will, according to Wilcox, emphasize

---

[128] Walter, p. 67.

[129] Ibid.

[130] Charles Wilcox, "Teachers Devise Three Year Lab Program," Chemical and Engineering News, 45, August 28, 1967, p. 74.

at all levels a sequential and conditional pattern of experimental work. The laboratory program could, in principle, accompany lecture sequences, but it dovetails most naturally the Hammond Curriculum[131] and the Advisory Council on College Chemistry modern experiments.[132,133] According to Wilcox, the first-year laboratory study will be aimed at a large number of nonmajors and smaller groups of chemistry majors.

The experiments developed by Harry Gray, Michael Smith, and Jurg Waser[134] of the California Institute of Technology advocate a different approach by including topics from diverse fields of chemistry. These three chemistry educators, in their preparation of introductory college chemistry experiments, have written experiments that show the interrelationship of inorganic and organic chemistry. One example is an experiment which involves the preparation of chromium (III) acetyl acetonate, its acetylation, and its oxidation to the triacid. The student then determines the triacid equilibrium constant and the magnetic susceptibility of the acid product. In addition, supplementary exercises have been written which would not only allow the capable student to prepare paramagnetic polymers of the triacid but would permit him to do a spectral analysis of the parent acid and its precursors.

The first-year laboratory equipment for the experiments described

---

[131]Hammond, p. 48.

[132]Modern Experiments in Introductory College Chemistry, Stanford University, California: Advisory Council on College Chemistry, 1966, p. 495.

[133]H. A. Neidig and William F. Kieffer, "Modern Experiments in Introductory College Chemistry," Journal of Chemical Education, Easton, Pennsylvania, 1967, Foreword.

[134]Wilcox, p. 74.

above would include gas chromatographs (GC), pH meters, and other special equipment. On the other hand, alternative experiments are provided that do not require such elaborate equipment. Laboratory techniques and methods for this first-year laboratory course include: volumetric analysis, separation of solid and liquid mixtures, distillation, crystallization and sublimation, extraction, chromatography, and electrochemistry.

Ernest H. Swift of the California Institute of Technology, says that since 1956, when he moved quantitative chemistry laboratory from the sophomore year to the first two quarters of the freshman year (with qualitative analysis given in the third quarter), at least 60 per cent more freshmen elect chemistry or chemical engineering at the end of their freshman year. Swift says:

> Quantitative techniques allow students to begin meaningful research much earlier, even as freshmen. The objectives of a quant course are not to train analysts or analytical chemists. Rather, it should develop a proficiency in planning, executing, and critically interpreting experiments involving quantitative measurement of various physical quantities.[135]

Suggested solutions to the problem of laboratory instruction differ mechanically rather than conceptually. Recently, a panel appointed by the Advisory Council on College Chemistry to study student laboratory programs concluded:

> The student has every right to expect that, on an hour-for-hour basis, the laboratory will be as stimulating as any of his activities at the university. It must compete. Does it? If not, the student is intellectually deprived.[136]

Although there is a difference of opinion among AC_3 panel members

---

[135]E. H. Swift, "Freshman Chemistry Laboratory at the California Institute of Technology," Journal of Chemical Education, 35 (1958) p. 44.

[136]Walter, p. 76.

regarding particular experiments to include in a program, there is a mutual agreement that laboratory is important for first-year chemistry courses. The panel was of the opinion that laboratory work in the first-year college chemistry course is moving rapidly toward quantitative experiments and that the level of such lab work demands student performance that is up to professional standards. According to AC_3, the current emphasis is on better techniques and comprehension, but fewer experiments are required. This trend, according to the panel,[137] is accompanied by the use of more instrumentation; freshmen at several schools have successfully performed experiments using instruments such as spectrophotometers and vapor chromatographs.

The panel suggested that the Advisory Council encourage a group of teachers to devise new laboratory experiments. These experiments would center on principles and ideas being introduced in first-year college courses. In addition, the panel felt that topics suitable for undergraduate research should be explored. Instead of fill-in-and-detach type laboratory texts and manuals, the use of research-type reports was urged.

The panel felt that some of the traditional lab experiments should be evaluated in light of new developments. For example, qualitative analysis, one of the oldest traditional lab exercises, should be re-examined to see if the principles demonstrated in this work can be presented more efficiently. Members of the panel believe that students should be encouraged to be more creative in applying these principles, rather than slavishly following a scheme for a given number of ions.

---

[137]King, "Modern Texts are Needed to Update College Chemistry Courses," p. 44.

Recently, the AC_3 Committee on Curriculum held a conference on unified laboratories at the University of North Carolina.[138] Several teachers discussed programs already in operation or planned at their schools. While there are differences in details of the unified laboratory programs outlined by the conference, there is general agreement that laboratory is essential for chemistry majors and that there are some essential aspects that any successful laboratory course must have. Describing the California Institute of Technology program, John Richards[139] expresses a philosophy that he felt should be applicable to laboratory for chemistry majors--fundamentally, chemistry is an experimental science and any course must therefore contain a reasonable amount of laboratory. Richards feels that an understanding of some of the many facets of the laboratory problem requires a prior understanding of the environment in which chemistry teachers are presently working. Richards discerned the current status of chemistry laboratory when he had this to say:

> Students coming to universities now are much better prepared in theoretical topics than they were ten years ago. This is a result of improved high school science courses. But in spite of their greater theoretical sophistication, students generally have not had more laboratory experience.[140]

Richards also pointed out other perplexing problems. For example, rapid advances in theoretical chemistry and the resulting increase in complexity of experimental methods have dictated that more theory be taught. Richards feels that the response to the felt need to teach more theory has resulted in an increase in the number of units required for

---

[138]Hume, p. 53.

[139]Ibid.

[140]Ibid., p. 54.

laboratory. To solve these problems, Richards urges that laboratory courses be taught in a new way, and more effectively and more efficiently. To do this, Richards says that more excitement, more enthusiasm, and more technique must be conveyed to students than has been the case. He lists four requirements for a good experiment to achieve these goals:

1. It should demonstrate a principle.
2. It should teach a useful, modern technique; students lose enthusiasm quickly if the experiments assigned are unrelated to modern chemistry.
3. It must challenge the student. Moreover, the student himself must recognize the challenge. There are many ways to accomplish this--for instance, by artful design of the experiment, and by introducing some unknown aspect to the experiment.
4. It should be open-ended.[141]

Richards believes that if an experiment is done under an oppressive deadline the student will go through it as rapidly as possible, probably with as little thought as possible, and will probably get little out of it. If, however, a student does not feel pressed to finish a large number of experiments in a short time, his appreciation of any given experiment will be greatly increased. In defense of the open-end experiments, Richards says:

> Some material will have to be left out of the course so that as a student becomes intrigued in an open-ended experiment he can pursue it in more depth than usual. This will mean that many students will not be exposed to every technique a teacher feels necessary for successful graduate research. But the time required to learn all the techniques to an appropriate degree of proficiency is simply not available in undergraduate programs.[142]

In Richards' opinion, a few experiments done well, thoughtfully, and creatively are much more valuable to students than simply having the

---

[141]Ibid., p. 53.

[142]Ibid., p. 54.

student go through as many "experimental recipes" as possible. Richards believes that students will be in the most advantageous position possible for further creative work as scientists if they are challenged with open-ended experiments with enough time allocated for a thorough, thoughtful job. Herbert O. House of Massachusetts Institute of Technology has a different view on the objective of the chemistry laboratory. In his view, the principal purpose for a chemistry major is to train him to do research. For a student not planning a research career, House feels a different type of laboratory course seems more appropriate.[143]

The rudiments of a first-rate laboratory program are inherent in the discussions of Richards[144] and the AC_3 panel member suggestions.[145] Even though there is a difference in opinion in regard to the end product--whether student becomes a research chemist or nonscience major--the open-ended experiment appears to be the pedagogically sound basis for achieving the objectives of general college chemistry laboratory as described by Richards.[146] The open-ended experiment, in the opinion of the investigator, would teach students execution and design of experiments and could be designed in such a manner as to show interrelationship of the different branches of chemistry as well as other disciplines of science and chemistry. The solution to the laboratory problem apparently lies in the understanding of the environment in which college professors of chemistry are working and the adaptability of open-ended experiments to fit their

---

[143]Ibid.

[144]Ibid.

[145]Ibid.

[146]Ibid.

situations.

General Summary of Literature Review

The extensive literature review shows the introductory college chemistry curriculum to be in the midst of a revolution and has been for some time. The diversity in views of different writers on what the introductory college chemistry course should be fortifies the statement[147] that no one knows just what the introductory college chemistry course is at present. The organization of the Advisory Council on College Chemistry and its vigorous activity in setting up conferences and the rapid dispensing of the writings of the panel members to the interested educators implies that an attempt is being made to consolidate and organize the introductory college chemistry curriculum in such a manner as to give structure to the discipline of chemistry. These conferences have one common weakness, however; with few exceptions, the reports carry this theme, "The remainder of this report reflects something of the diversity of opinion expressed by the participants."[148] Why not cooperation, rather than indifference?

Some educators recognize a number of forces in operation in our chemical educational environment. They recognize the flood of new information appearing in the chemical literature, especially that currently being published by the Advisory Council on College Chemistry and the American Chemical Society, and the rapid developments of complete new disciplines where there was once a borderline. They recognize the larger

---

[147]Walter, p. 524.

[148]Haenisch, p. 4.

numbers of students beginning the study of college chemistry and the fact that many of these students are better prepared in terms of high school chemistry and mathematics. They recognize that more equipment is available for instructional use in introductory college chemistry lecture and laboratory, and that with this equipment, some very sophisticated experiments and/or demonstrations can be moved from the upper grade levels or the graduate level to the freshman level. Some of the chemistry educators are responding to these forces by making an effort to bring their students in contact with the frontier of chemistry and are making an effort to create for their students a sense of participation in the processes of chemistry.

The revision of introductory college chemistry curricula, in response to the operation of some of these forces, was apparent in the discussions of George Hammond[149] and Charles Wilcox.[150] Hammond and Wilcox, through their new innovations, are adding structure to the discipline of chemistry; and they are using the chemistry laboratory to accomplish the objective it should achieve--that is, to teach students execution and design of experiments. Wilcox is coordinating the laboratory content with lecture material. The recurring theme of Wilcox's laboratory phase is "how to engineer an experiment." The curricula of Hammond and Wilcox carry one common ingredient--the student uses and develops his rational powers.[151]

---

[149]Hammond, p. 48.

[150]Wilcox, p. 74.

[151]Educational Policies Commission, <u>The Central Purpose of American Education</u>, Washington, D. C., NEA, 1962, p. 12.

Emphasis is being placed upon the coordination between chemistry teachers and those in other sciences with a view toward reducing duplication and increasing the transfer of useful principles and information. Edward D. Fuller and the Advisory Council on College Chemistry panel members[152] discussed the use of multidisciplinary courses as the vehicle to give structure to the discipline of chemistry and to give better learning by closely relating aspects of one discipline with a course in another.

John Richards[153] feels that in spite of the improved academic preparation high school students generally have not had adequate laboratory experience. Richards suggested open-ended experiments to overcome this limitation.

The curriculum proposals on introductory college chemistry, in general, are coming from large universities. One is impressed by the programs presented by these chemists on "how I do it"; but, on the other hand, one is puzzled as to what is happening in the other institutions of higher education. Regardless of size of the institutions, it appears that most educators agree that the development of a hard core of topics is necessary to guide what is to be taught in an introductory college chemistry course. The AC_3 Committee on General Chemistry placed a tag on the controversy regarding the selection of a core of topics, even though Young had laid the framework, when they wrote:

> No attempt was made to outline a single introductory course. Rather, consideration was given to a number of specific topics and specific methods of instruction which might be appropriate for freshman chemistry and which are now in limited operation. Hopefully, these suggestions will stimulate further consideration

---

[152]Fuller, pp. 66-67.

[153]Hume, p. 53.

of the methods and content of introductory chemistry.[154]

Nelson McKain, Jr.,[155] pointed out some inherent weaknesses common to many of the new course proposals: (1) The objectives of the course were not stated and (2) the courses do not consider the students for whom they are primarily intended. Also, many of the proposed courses make no mention of evaluation or, if it is mentioned, the criteria for evaluation are so elusive and lacking that one is left pondering. Motivation is constantly discussed but remains the unsolved problem.

The problem then is this: Given the data which comprise the problems in chemistry and given recommendations for solutions, how can the members of the chemistry education profession resolve the personal differences in opinion regarding the application of chemical principles toward the purpose of chemistry's contribution to general education and achieve a structural pattern out of the chaos and indifference? Is such a trend evident? The evidence is far from conclusive that professional chemistry educators know what they are doing in introductory college chemistry. The findings from a survey of the teaching practices in introductory college chemistry, on the assumption that the data would indicate trends, could be of value to interested groups. Someone has said that chemistry is an experimental science; so too is its teaching.[156] Granted that this statement is valid, why don't chemists, as professional educators, get together somewhat like the secondary school innovators, consolidate their differences, and structure some introductory college chemistry courses around some stated

---

[154]Haenisch, p. 4.

[155]McKain, p. 4.

[156]"Editorially Speaking," p. 115.

behavioral objectives, and then devise measures to assure whether or not these goals have been achieved? The ground rules for the selection and rejection of topics have been formulated as shown by the suggestions of Babor, Deming, Mysels and Copeland, Cavelti, Nash and AC_3, and Shotton.[157] The goals and requirements of a good laboratory experiment were well defined by Adams, Summerbell, and Richards[158] in the previous discussions.

The investigator's conclusions from the literature survey are (1) the introductory college chemistry course is in the midst of a revolution, (2) no one knows the nature of the introductory course at the present time, (3) there is some emphasis upon cooperation between disciplines in the introductory course, and (4) that the evidence is far from conclusive that professional chemistry educators know what they are doing in introductory college chemistry. The research in the literature, when correlated with the controversial discussion from the literature, shows the need for the survey.

---

[157]The guidelines for the selection or rejection of topics were described by these aforementioned writers on pages 24, 25, 26, 27, 25, and 22 in this dissertation, respectively.

[158]The general objectives and rudiments pertinent to the well-designed laboratory experiment were defined in the discussions of these aforementioned chemistry educators on pages 21, 43, and 53-54 in this dissertation, respectively.

CHAPTER III

DESIGN OF THE SURVEY

Selection of a Population

The initial statement of the problem has shown this investigation to be broad in scope. The purpose of the survey is to determine the present objectives, methods, and materials used in teaching introductory college chemistry in selected accredited colleges and universities. In order to investigate the teaching practices used in introductory college chemistry courses, sending questionnaires to those instructors in American colleges and universities who teach these courses was necessary. Institutions listed in the Office of Education directory[159] defined the population. In general, the classification scheme of institutions of higher education which was used in the questionnaire is the system in current use by the United States Office of Education.

CLASSIFICATION SCHEME: University refers to those institutions which give considerable stress to graduate instruction, which confer advanced degrees as well as bachelor's degrees in a variety of liberal arts fields, and which have at least two professional schools that are not exclusively technological. College of Liberal Arts refers to those institutions in

---

[159] Accredited Institutions of Higher Education. Washington: American Council on Education, September, 1967.

which the principal emphasis is placed on a program of general undergraduate education. Junior Colleges are institutions offering two-year programs of study beyond the level of the secondary school which can be credited toward a baccalaureate degree. Specialized Institutions is the category which includes schools offering degree programs directed toward one or more fields of specialization that are not attached to a liberal arts college or university. These institutions are usually adapted to such fields as technology, teacher education, and theology.

Two United States Department of Health, Education and Welfare Publications (1) Opening Fall Enrollment in Higher Education, 1966, and (2) Accredited Institutions of Higher Education (September, 1967) listed the following enrollment data for colleges and universities for the fall semester of 1966:

TABLE 1. THE 1966 FALL SEMESTER ENROLLMENT

Type of Accredited Institution	Number (N)	Enrollment Sept., 1966	Percent of Total	Mean (M)
1. Universities	236	2,753,514	47	11,667.4
2. Liberal Arts	793	1,649,232	28	2,079.7
3. Junior Colleges	400	1,081,250	18	1,703.1
4. Specialized	207	410,849	7	1,984.7
Total	1,636	5,894,845	100	3,603.2

According to Neyman,[160] the foregoing classification scheme suggested

[160] J. Neyman, "On the Two Different Aspects of the Representative Method," Journal of the Royal Statistical Society, 97 (1934) pp. 558-606.

a stratified-random sampling. Whenever a population, such as the total number of colleges and universities, is divided into such categories and some kind of random sample is taken in each category, the sample is called a <u>stratified</u> sample; the categories from which the sample is drawn are called <u>strata</u>; and the process of dividing this population into categories is called <u>stratification</u>. After eliminating institutions known to be closed or merged and deleting those colleges who offer graduate work only, the final list of 1,636 institutions (Table 2) was made up from those lists in the 1967 <u>Accredited Institutions of Higher Education</u> directory.

TABLE 2. NUMBER OF ACCREDITED INSTITUTIONS OF HIGHER EDUCATION IN THE CONTINENTAL UNITED STATES IN 1967 OFFERING INTRODUCTORY COLLEGE CHEMISTRY

State	Number of Institutions	State	Number of Institutions
Alabama	25	Nebraska	16
Arizona	8	Nevada	1
Arkansas	17	New Hampshire	8
California	172	New Jersey	29
Colorado	19	New Mexico	10
Connecticut	22	New York	139
Delaware	3	North Carolina	55
District of Columbia	15	North Dakota	8
Florida	34	Ohio	53
Georgia	45	Oklahoma	25
Idaho	8	Oregon	27
Illinois	73	Pennsylvania	93
Indiana	31	Rhode Island	10
Iowa	35	South Carolina	22
Kansas	31	South Dakota	13
Kentucky	31	Tennessee	40
Louisiana	20	Texas	83
Maine	11	Utah	9
Maryland	35	Vermont	13
Massachusetts	67	Virginia	38
Michigan	45	Washington	30
Minnesota	28	West Virginia	18
Mississippi	30	Wisconsin	30
Missouri	49	Wyoming	3
		TOTAL	1,636

Stratification

The survey was made on the basis of a sample drawn at random from 1,636 accredited institutions apparently in operation at the time. The first step used in designing the sample was to group the 1,636 institutions into four type strata of N_1, N_2, N_3, and N_4. In stratified sampling, the population of N units (1,636 institutions) is first divided into subpopulations of N_1, N_2, ..., N_L units respectively. These subpopulations are non-overlapping and together they comprise the whole of the population so that

$$N = N_1 + N_2 + N_3 + N_4$$

All institutions in the population = 1,636

To obtain the full benefit from stratification, the values of Nh (h = the population values of N_1, N_2, N_3, and N_4, respectively) must be known. When the strata had been determined, a sample was drawn from each stratum, the drawing made independently in different strata. The sample sizes within the strata were denoted by n_1, n_2, ..., n_L, respectively. The four strata were based on size, the 236 largest institutions (1966 fall enrollment) in group 1; the 400 smallest in group 4. These classifications were a compromise between the desire to report the most meaningful statistics and the practical need for holding categories to a minimum in order to facilitate and minimize the task of securing information by sampling methods.

According to Cochran,[161] stratification may bring about a gain in precision in the estimates of the whole population. The basic idea is to determine the status of introductory chemistry within each stratum as well

---

[161]William G. Cochran, Sampling Technique. New York: John Wiley and Sons, Inc., 1953, p. 65.

as the status for the whole population. This method of stratification was selected as the data for the subdivisions of the population (Table 1) were known and as sampling problems may differ markedly in different parts of the population. Sampling was feasible because lists of institutions (Tables 1 and 2) were available, as were enrollment statistics for practically all institutions for the 1966-67 school year.

According to Cornell,[162] (in the principle of optimum allocation) the allocation of sample size in the respective strata for a fixed total sample size requires the fewest cases to yield a given level of realiability if they are distributed among strata in proportion to the product of the number of colleges in a given population (universe) stratum. The decision to use the method of optimum allocation to determine sample size was based upon the fact that data was available (Table 1) which would allow the determination of allocations. The availability of enrollment data, according to Cornell, permits a gain in efficiency of design through stratifications. Sampling was necessary because limited resources were available and results were desired as quickly as possible.

Types of Estimates to be Used

The formulas to be used for the calculation of estimates from each classification of institution were selected from Cornell[163] and Cochran.[164] These researchers have developed the statistics for studies which utilized the method of stratified random sampling. The formula selected, adapted

---

[162]F. G. Cornell, "A Stratified-Random Sample of a Small Finite Population," Journal of American Statistical Association, 42 (1947) p. 523.

[163]Ibid.

[164]Cochran, p. 67.

from Cornell,[165] is:

$$\hat{S} = \sum_{h=1}^{L} \frac{N_h}{n_h} \sum_{i=1}^{n_h} Y_{hi} \tag{1}$$

where $\hat{S}$ is the estimated total enrollment of all institutions in all L (L=4) strata of institutions, $\underline{N}$ is the total number of institutions in the universe or population; $\underline{N_h}$ is the total number of institutions in the $\underline{h}$th stratum; $\underline{n}$ is the number of institutions in the sample from all strata; $\underline{n_h}$ is the number of institutions in the sample's $\underline{h}$th stratum; and Y_{hi} is the enrollment of the $\underline{i}$th institution in the $\underline{h}$th stratum. The symbol $\wedge$ is used to denote an estimate of the population characteristic from the sample.

Notation

The suffix $\underline{h}$ denotes the stratum and $\underline{i}$ the enrollment within the stratum. The following symbols all refer to stratum $\underline{h}$. (Capital letters refer to characteristics of the population and lower letters refer to those of the sample).

N_h = total number of institutions in the $\underline{h}$th stratum of the population.
n_h = number of institutions within each $\underline{h}$th stratum of the sample.
Y_{hi} = enrollment of the $\underline{i}$th institution in the $\underline{h}$th stratum.

$$\bar{Y}_h = \frac{\sum_{i=1}^{N_h} Y_{hi}}{N_h} = \text{true mean} \tag{2}$$

$$\bar{y}_h = \frac{\sum_{i=1}^{n_h} \bar{y}_{hi}}{n_h} = \text{sample mean} \tag{3}$$

---

[165]Cornell, p. 523.

$$S_h^2 = \frac{\sum_{i=1}^{N_h} (y_{hi} - \overline{Y}_h)^2}{N_h - 1} = \text{true variance} \tag{4}$$

S_h = stratum standard deviation

For the population mean per unit, y_{st} (st for stratified), Cochran[166] suggests the formula

$$y_{st} = \frac{\sum_{h=1}^{L} N_h\, y_h}{N} \tag{5}$$

as the simplest type of estimate appropriate to stratified sampling, where $N = N_1 + N_2 + \ldots + N_L$.

Determining the Size of the Sample

The problem of optimum allocation, the allocation of sample size in the respective strata for a fixed total sample size when the sampling variance is minimum, concerns the choice of the sample sizes $\underline{n_h}$ in the respective strata. In stratified random sampling, according to Cochran,[167] the variance of the estimated mean $\underline{y_{st}}$ is the smallest for a fixed total size of sample, if the sample is allocated with $\underline{n_h}$ proportional to N_hS_h. Cochran gives the formula below to show that the sample size in a stratum should be proportional to the product of the size of the stratum and the standard deviation of the stratum, or, in other words, that the sampling fraction $\underline{n_h}$ should be proportional to the $\underline{N_h}$ standard deviation (Appendix A):

$$n_h = n \frac{N_hS_h}{\Sigma\, N_hS_h} \tag{6}$$

---

[166]Cochran, p. 82.

[167]Ibid.

An expression for the minimum variance, V, is obtained by substituting the values of $\underline{n_h}$ given by formula (6) into the general formula, developed by Cornell (1947),[168] for $V(y_{st})$, where

$$V\ (y_{st}) = \frac{1}{N^2} \sum_{h=1}^{L} N_h(N_h - n_h) \frac{Sh^2}{n_h} \tag{7}$$

to give

$$V \min\ (y_{st}) = \frac{1}{N^2} \frac{(\ \Sigma\ N_hSh)^2}{n} - \frac{1}{N^2} \Sigma\ N_h(S_h)^2 \tag{8}$$

The method of optimum allocation requires advance estimates of the stratum standard deviation $\underline{S_h}$. The estimate of the standard deviation was obtained from the data shown in Tables 1 and 3. The stratum standard deviation was calculated by taking the square root of the true variance equation (Equation 4) to yield

$$S_h = \sqrt{\frac{\sum_{i=1}^{N_h} (y_{hi} - \overline{Y}_h)^2}{N_h - 1}} \tag{9}$$

Cochran[169] showed that the fewest cases will be required to yield a given level of reliability if they are distributed among strata in proportion to N_hS_h; that is,

$$\frac{n_h}{n} = \frac{N_hS_h}{\sum_{h=1}^{L} N_hS_h}\ , \tag{10}$$

or

$$nh = n\ \frac{N_hS_h}{\Sigma\ N_hS_h}\ , \tag{11}$$

---

[168]Cornell, p. 526.

[169]Cochran, p. 65.

where n is the number of institutions in the sample from all strata, i.e.,

$$n = \sum_{h=1}^{L} nh \quad . \tag{12}$$

The formula for determining n was derived by Cochran[170] from Equations 8, 11, and 12:

$$n = \frac{\left(\sum_{h=1}^{L} N_h S_h\right)^2}{V + \sum_{h=1}^{L} N_h S_h{}^2} \tag{13}$$

or, simplifying,

$$n = \frac{(\Sigma\, N_h S_h)^2}{V + \Sigma\, N_h S_h{}^2} \tag{14}$$

Since the equations for the variances of the estimated mean, Equations (1) and (2), contain both the n_h and the S_h, sample size was not determined until advance estimates of the S_h were available and some decision about allocation was made. In this survey, the standard error was not set. Instead, the coefficient of variation (C.V.) adapted from Cornell,[171] was set as follows:

$$C.V. = \frac{\sigma\ s}{S} = 0.05 = V \text{ (true variance)} \tag{15}$$

This formula was used since Cornell had shown that the variance of the estimate of the enrollments, $\sigma\ s^2$, in formula (1) was equivalent to

$$\sum_{h=1}^{L} \frac{(N_h{}^2 S_h{}^2}{n_h} \cdot \frac{N_h - n_h)}{N_h - 1} \tag{16}$$

or the desired variance, V, equals the square of the desired standard error, $\sigma\ s^2$.

---

[170]Cochran, p. 66.

[171]Cornell, p. 526.

Since the investigator is more willing to accept false data than reject true data, the desired limit of error was set at 5 per cent. Thus, the desired standard error, according to Equation (15), is 0.05 x S, where S is the total enrollment of all desired institutions, so that the desired variance is V = $0.0025 \times S^2$. It may be objected that enrollments will presumably be greater in 1967 than 1966 and that allowance should be made for this increase. Actually, the calculations assume only that the coefficient of variation (CV) per college remains the same in 1967--an assumption which may be questionable; but, because of the availability or unavailability of data in September, 1967, the investigator was forced to make it. Hence, Equation (14) was applied in the following form:

$$n = \frac{(\Sigma\ N_h S_h)^2}{0.0025\ S^2 + \Sigma\ N_h S_h^2} \tag{17}$$

The allocation using equation (15) was based upon enrollments in the fall of 1966.

TABLE 3. ANALYSIS OF 1966 ENROLLMENT STATISTICS ON BASIS OF WHICH ALLOCATION OF CASES WAS MADE AMONG FOUR STRATA OF COLLEGES AND UNIVERSITIES

Stratum	h	S	S_h	$N_h S_h$	$N_h S_h^2$	n_h
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Universities	236	2,753,514	10,401	2,454,634	25,530,623,688	130
Liberal Arts	793	1,649,232	2,885	2,287,805	6,599,814,781	121
Junior Colleges	400	1,081,250	3,534	1,413,600	4,996,312,677	75
Specialized	207	410,849	2,273	470,511	1,069,066,925	25
Total	1,636			6,626,466	38,195,818,071	351

Allocation Procedure Illustrated

The allocation procedure is illustrated below. The 1966 fall total enrollment for the 1,636 institutions, S, was 5,894,845. Table 3 shows the other data which are needed to solve Equation (9).

$$n = \frac{43911151649401}{0.0025x5894845 + 38196120364} = \frac{43911151649401}{86872993935 + 38196120364} = 351.09 = 351$$

This number is distributed according to Equation (17) by means of the N_hS_h values of strata 5, column 5, of Table 3. The results of the selection of sample size in each stratum from (17) are as follows:

$$n_1\text{(Universities)} = 351 \times \frac{2454633}{6626549} = 129.87 = 130$$

$$n_2\text{(Liberal Arts)} = 351 \times \frac{2287805}{6626549} = 121.09 = 121$$

$$n_3\text{(Junior Colleges)} = 351 \times \frac{1413600}{6626549} = 74.76 = 75$$

$$n_4\text{(Specialized)} = 351 \times \frac{470511}{6626549} = 24.92 = 25$$

The results, after rounding to whole numbers, appear in column 7 of Table 3.

The statistical calculations for sample size as shown in Table 3 at the 5 per cent limit of error, resulted in the acceptance of 130 universities, 121 liberal arts colleges, 75 junior colleges, and 25 specialized institutions; a total of 351 colleges and universities as the whole sample.

Selection of Sample

The accredited institutions of higher education, within a given stratum, were arranged in alphabetical order and were assigned numbers. The desired number of colleges within each stratum was selected by drawing a sample using a table of random numbers.[172]

---

[172] Wilfrid J. Dixon and Frank J. Massey, Jr., Introduction to Statistical Analysis. New York: McGraw and Hill Book Company, Inc., 1951, pp. 290-294.

In practice, the simple random sample was drawn unit by unit. The units in the population (from each state) were numbered from 1 to N_h. A series of random numbers between 1 and N_h were drawn by means of a table of random numbers.[173] The sampling described was without replacement; that is, a number that had been drawn previously was ignored since there seemed little point in having the same unit twice in the sample.

Efficiency Gained by Stratification Within the Four Type Categories

At this point it is of significance to note the efficiency which results from the stratified-random design with optimum allocation as described above. According to Cornell,[174] the usual means of determining the efficiency of a stratified sample is a comparison with an unrestricted random sample (simple random sample). If there was no stratification, that is to say, if all colleges and universities had been lumped together with the same type of estimate as in Equation (1), all institutions would, in effect, become one single stratum and the variance of the estimated total enrollment, according to Cornell,[175] would be calculated from the following equation:

$$\sigma\ s^2 = \frac{N^2 S_h{}^2}{n} \quad \frac{(N - n)}{(N - 1)} \tag{18}$$

Substituting the proper values into Equation (18) from the data in Table 3, page 71 yields the following value for $\sigma\ s^2$:

$$\sigma\ s^2 = \frac{(1636)^2\ (3864)^2}{351} \quad \frac{(1285)}{(1635)} = 206{,}006{,}000{,}000$$

---

[173] Ibid.

[174] Cornell, p. 529.

[175] Ibid.

The variance for all 1636 colleges and universities, as shown by Equation 14, is 86872993935. The desired stratified-random design was geared to a standard error of 294,742 or a variance of $(294{,}472)^2$, which is approximately 87,000,000,000.

The simple random sample variance, using Equation (18) was calculated to be approximately 206,000,000,000. According to Cornell,[176] the stratified plan used in the survey is $\frac{206{,}000{,}000{,}000}{87{,}000{,}000{,}000}$ or 2.3 times as efficient as the unrestricted random design would have been. The number of cases required on a random basis to produce the desired standard error of 294,742 would, according to Cochran,[177] be $n_o = \frac{S^2}{V}$ where n_o is a satisfactory approximation to the n of Equation (18). Substituting the data from Table 3 into the equation yields a value of $\frac{(4{,}876{,}434)^2}{206{,}000{,}000{,}000} = 1154$. Since the franction $\frac{n_o}{N}$ is appreciable (that is, ($\frac{n_o}{N}$ equals $\frac{1154}{1636} = 0.71$) the following equation, adapted from Cochran,[178] was used:

$$n = \frac{n_o}{1 + \frac{n_o}{N}} \tag{19}$$

Substitution of the n_o value into Equation (19) yields:

$$n = \frac{1154}{1 + \frac{1154}{1636}} = 675.$$

The sample size of 675 would have required 41 per cent of the 1636 cases.

Administration and Distribution of the Questionnaire

The questionnaire was mailed to college professors who teach the introductory college chemistry courses and a stamped, self-addressed

---

[176]Ibid., p. 526.

[177]Cochran, p. 52.

[178]Ibid.

envelope was enclosed. There were two follow-ups to each questionnaire. The first was in the form of a letter with an attached postal card. The addressee was informed that a completed questionnaire had not been received from his institution, but was greatly desired. The accompanying self-addressed, return postal card contained statements to be checked by the recipient indicating disposal of the questionnaire. The card contained statements which a non-respondent could check to give reasons why he did not participate in the survey. Later, a letter signed by the investigator, was sent with a duplicate questionnaire to those who had not replied. A fair response to the appeal for completed questionnaires was had. Returns were received from colleges in all parts of the United States and from all four classifications. Only one questionnaire was returned which was not completed; two were returned about two-thirds completed and four were returned by the respondents indicating their courses do not correspond to the objectives of the survey. The tabulations of all data from completed questionnaires were made with the exception of some few individual suggestions and/or criticisms regarding procedure and materials which the investigator felt was not germane to the survey findings.

Characteristics of the Distribution

A distribution of the returns by state and classification is presented in Tables 4, 5, and 6. Those data show the number of institutions in each state to which questionnaires were sent, the number of completed returns received, and the percentage of return.

According to Garland G. Parker,[179] there are more than 2,100

---

[179]Garland G. Parker, "Statistics of Attendance in American Universities and Colleges, 1966-67," School and Society, January 7, 1967.

institutions of higher education in the United States. The exclusion of graduate schools, medical schools, some theological schools, non-accredited institutions, and other institutions that do not offer first-year college chemistry from the total number of institutions resulted in the selection of 1,636 colleges and universities as the population.

TABLE 4. DISTRIBUTION OF QUESTIONNAIRES RECEIVED FROM INSTITUTIONS BY STATES

State	Number Sent	Number Returned	Percentage Return
Alabama	8	4	50
Arizona	1	0	0
Arkansas	2	2	100
California	32	17	53
Colorado	3	3	100
Connecticut	7	4	57
Delaware	1	1	100
District of Columbia	2	2	100
Florida	6	4	67
Georgia	12	11	92
Idaho	2	2	100
Illinois	23	16	70
Indiana	8	4	50
Iowa	4	2	50
Kansas	7	4	57
Kentucky	11	3	27
Louisiana	4	3	75
Maine	2	2	100
Maryland	4	3	75
Massachusetts	14	9	64
Michigan	9	8	89
Minnesota	5	5	100
Mississippi	6	4	67
Missouri	7	4	57
Montana	1	0	0
Nebraska	6	4	67
New Hampshire	2	1	50
Nevada	1	1	100
New Jersey	7	4	57
New Mexico	2	0	0
New York	27	8	30

TABLE 4. (Continued)

State	Number Sent	Number Returned	Percentage Return
North Carolina	8	4	50
North Dakota	1	0	0
Ohio	18	6	33
Oklahoma	7	5	71
Oregon	7	4	57
Pennsylvania	19	10	53
Rhode Island	1	0	0
South Carolina	5	2	40
South Dakota	4	4	100
Tennessee	10	8	80
Texas	15	10	67
Utah	2	0	0
Vermont	1	1	100
Virginia	9	8	89
Washington	8	6	67
West Virginia	5	4	80
Wisconsin	5	5	100
Wyoming	0	0	0
TOTAL AND MEAN PERCENTAGE RETURN	351	212	60.4

The data in Table 4 indicate that the response to the questionnaire was geographically distributed. There are no returns from six states: Arizona, Montana, New Mexico, North Dakota, Rhode Island and Utah. From colleges and universities in Arkansas, Colorado, Delaware, District of Columbia, Idaho, Maine, Minnesota, Nevada, South Dakota, Vermont, and Wisconsin, 100 per cent of the questionnaires were completed and returned. From institutions in Georgia, Illinois, Louisiana, Maryland, Michigan, Oklahoma, Tennessee, Virginia, and West Virginia, 70 to 92 per cent were returned. Colleges from 18 states returned 50 to 67 per cent of the questionnaires. Institutions from the remaining 4 states returned from 27 to 40 per cent.

Sampling by Classification of Institutions

The distribution of institutions by classification returning questionnaires is shown in Table 5. The classifications used in the questionnaire are those used by the United States Office of Education: 1. universities, 2. liberal arts colleges, 3. junior colleges, and 4. specialized institutions. Space was provided in the questionnaire for indicating classification.

TABLE 5. DISTRIBUTION OF QUESTIONNAIRES RECEIVED BY CLASSIFICATION

		Classification of Institutions			
State	Total Returns	Universities	Liberal Arts	Junior College	Specialized Institutions
Alabama	4	1	3	0	0
Arizona	0	0	0	0	0
Arkansas	2	1	1	0	0
California	17	2	6	9	0
Colorado	3	2	0	1	0
Connecticut	4	3	1	0	0
Delaware	1	1	0	0	0
District of Columbia	2	1	1	0	0
Florida	4	4	0	0	0
Georgia	11	0	4	7	0
Idaho	2	2	0	0	0
Illinois	16	5	3	5	3
Indiana	4	0	3	0	1
Iowa	2	1	1	0	0
Kansas	4	2	1	1	0
Kentucky	3	3	0	0	0
Louisiana	3	1	1	1	0
Maine	2	1	0	1	0
Maryland	3	1	2	0	0
Massachusetts	9	2	5	1	1

TABLE 5. DISTRIBUTION OF QUESTIONNAIRES RECEIVED BY CLASSIFICATION (Continued)

		Classification of Institutions			
State	Total Returns	Universities	Liberal Arts	Junior Colleges	Specialized Institutions
Michigan	8	5	2	1	0
Minnesota	5	0	4	1	0
Mississippi	4	1	0	3	0
Missouri	4	2	2	0	0
Montana	0	0	0	0	0
Nebraska	4	1	3	0	0
New Hampshire	1	1	0	0	0
Nevada	1	1	0	0	0
New Jersey	4	2	0	0	2
New Mexico	0	0	0	0	0
New York	8	4	2	1	1
North Carolina	4	1	3	0	0
North Dakota	0	0	0	0	0
Ohio	6	1	5	0	0
Oklahoma	5	2	1	2	0
Oregon	4	3	0	0	1
Pennsylvania	10	4	3	1	2
Rhode Island	0	0	0	0	0
South Carolina	2	1	1	0	0
South Dakota	4	2	1	0	1
Tennessee	8	2	5	1	0
Texas	10	6	2	2	0
Utah	0	0	0	0	0
Vermont	1	0	1	0	0
Virginia	8	2	4	2	0
Washington	6	4	1	1	0
West Virginia	4	2	2	0	0
Wisconsin	5	2	3	0	0
Wyoming	0	0	0	0	0
TOTAL	212	82	77	41	12

There are 212 completed questionnaires in the survey, of which 82 were received from universities, 77 from liberal arts colleges, 41 from junior colleges, and 12 from specialized institutions. From institutions in the four classifications, 63 per cent were received from universities, 64 per cent from liberal arts colleges, 55 per cent from junior colleges, and 48 per cent from specialized institutions.

A fair distribution (see Tables 4, 5 and 6) of colleges, both as to geographical location and classification represented, was obtained. The distribution by classification and by state is presented to show the general coverage of the survey and not for statistical justification.

TABLE 6. DISTRIBUTION OF QUESTIONNAIRES RECEIVED FROM INSTITUTIONS BY CLASSIFICATION

Classification	Number Sent	Number Returned	Number Applicable	Per Cent Returned
1. Universities	130	84*	82	63
2. Liberal Arts	121	77	77	64
3. Junior Colleges	75	41	41	55
4. Specialized	25	13**	12	48
TOTAL	351	215	212	60

*One university questionnaire was two-thirds complete and one university offered multidiversity course that did not apply.
**General Chemistry was part of General Science Course.

The Plan of Presentation of Data

The results of the survey will be presented in forthcoming tables which will describe the number and characteristics of the introductory college chemistry courses, the professional training of those professors who teach these courses, the objectives of the introductory college chemistry courses, the individual methods used by college professors to evaluate the courses and the materials and methods used in teaching introductory college chemistry. These summations of data follow, in general, the outline as presented in the questionnaire. The topics are listed under six divisions, including twenty subdivisions; namely,

1. What are the characteristics of the introductory college chemistry courses in relation to:
   a. the number of different course titles.
   b. the number of different courses per college or university.
   c. the course prerequisites.
   d. the number of semester hours per introductory course per year.
2. What is the student's high school chemistry experience prior to enrollment in introductory college chemistry?
3. What per cent of the introductory college chemistry students eventually major in chemistry?
4. What is the academic background and field specialization of college professors who are responsible for teaching introductory college chemistry?
5. What is the professional training and responsibilities of student assistants?
6. What is the typical introductory college course(s) being offered?
7. What is the teacher reaction to the utility of the current available textbooks and laboratory manuals?
8. What is teacher opinion as to what the introductory college chemistry course should be?
9. Have new introductory chemistry courses been added the past two years?
10. Has textbook change or revision and/or laboratory exercise changes or revision in the introductory chemistry course occurred in the last

two years?

11. What is the nature of the new course when compared to the old course?

12. What is the description of the introductory college chemistry laboratory with respect to:

    a. description of laboratory manual or text in use.

    b. type of pre-laboratory instruction.

    c. how students handle experimental data.

    d. what type of laboratory reports is expected of introductory college chemistry students?

13. What provisions are made to challenge academically prepared students, i.e., honors courses, independent study, conference study or sessions, advanced placement? What is the nature of the honors course? How are the students selected? What is the teacher rating in regard to best method of selection? What is the nature of independent study? Do current texts meet the needs of an honor course or independent study? What is the best description of the conference study or session? What is the nature of advanced placement? If no provisions are made for the academically talented student, what factors are given for non-participation?

14. What are the current objectives and aims of the introductory college chemistry course, especially the first five choices?

15. How are introductory college chemistry students and courses evaluated?

16. What supplementary materials, equipment, outside materials, methodology and techniques are being used to assist in the teaching of

introductory college chemistry?

17. What do college professors feel to be the major limiting factors that tend to reduce student interest in introductory college chemistry?
18. What do college professors feel to be the chief factors responsible for alteration in introductory college chemistry courses?
19. What are the selected topics currently being taught in introductory college chemistry?
20. How do the findings of the survey compare with the suggestions that have been offered by the Advisory Council on College Chemistry?

Responses on the questionnaire were entered on punch cards; the data was normalized to a semester basis; a computer program was written (see Appendix H) and the data was then correlated on an IBM 1110 Computer.

The t-test was used to determine whether there is a significant difference in the practices, opinions, or methodologies of the four classifications of the population. In general, the statistical measures employed were: per cent; the mean; the standard deviation of the mean; the standard error of difference between the two uncorrelated means; and the critical ratio (t-test). Since the investigator is more willing to accept false data than reject true data, the 5 per cent level of significance was chosen as criterion.

As a basis for discussion, when 75 per cent of the replies are in agreement, the objective or statement is taken as generally accepted; and, when 67 per cent agree, there is a sufficient majority to say that the objective is accepted by most professors. A percentage of 55 to 66 indicates only possible acceptance; conversely, a response of less than 33 per cent indicates a rejection or low usage. A variation of ± 5 per cent was allowed in each instance.

CHAPTER IV

DESCRIPTION OF INTRODUCTORY COLLEGE CHEMISTRY COURSES OFFERED IN INSTITUTIONS

The respondents were requested to supply the investigator with a description of the introductory college chemistry course(s) offered in their respective institutions. The instructions to the respondents requested them to list the following information with respect to the different introductory college chemistry courses offered: course number, course title, course enrollment per year, pre-requisite(s), and course credit in semester hours. The respondents were specifically instructed to omit courses for non-science majors, or pre-nursing courses and the like that do not meet prerequisite requirements for further courses in their chemistry curriculum. The ensuing description of the introductory college chemistry course is based on data obtained from the response to Part I of the questionnaire. Many respondents, rather than complete section I of the questionnaire which requested a description of courses, either submitted pages from the college catalog or sent catalogs describing introductory chemistry courses offered. These catalog descriptions reveal a variation in course titles as well as in the description of the courses.

The Advisory Council on College Chemistry, in 1964, recommended that a term other than "General Chemistry," be used to describe the introductory

TABLE 7. THE NUMBER OF DIFFERENT COURSE TITLES OF INTRODUCTORY CHEMISTRY COURSES

Course Titles	No. of Courses Under Each Title				
	Univ.	L.A.	J.C.	S.I.	Total
1. Analytical Chemistry	0	0	1	0	1
2. Atoms, Molecules, and Ions	0	1	0	0	1
3. Basic Principles of Modern Chemistry	1	0	0	0	1
4. Beginning Chemistry	0	0	2	0	2
5. Chemistry	2	1	4	1	8
6. Chemistry Laboratory Techniques	1	0	0	0	1
7. Chemical Periodicity	1	0	0	0	1
8. Chemical Principles and Introductory Analysis	0	1	0	0	1
9. Chemistry-Physics	1	0	0	0	1
10. Chemistry Survey	0	1	0	0	1
11. College Chemistry	0	0	1	0	1
12. Elements of Chemistry	0	0	1	0	1
13. Fundamentals of Chemistry	3	5	1	0	9
14. Foundations of Chemistry	1	0	0	0	1
15. General Chemistry	99	61	32	11	203
16. General Chemistry for Engineers	0	0	0	1	1
17. General Chemistry with Analysis	0	0	0	1	1
18. General Chemistry and Qualitative Analysis	1	1	1	0	3
19. General Inorganic Chemistry	0	0	3	1	4
20. General and Physical Chemistry	1	0	0	0	1
21. Inorganic Analysis	0	1	0	0	1
22. Inorganic Chemistry	7	12	2	1	22
23. Inorganic Chemistry and Qualitative Analysis	0	2	0	0	2
24. Intermediate General Chemistry	0	0	0	1	1
25. Ionic Reactions of Equilibria	1	0	0	0	1
26. Integrated Sequence of Undergraduate Chemistry	1	0	0	0	1
27. Introduction to Chemistry (Introductory Chemistry)	13	5	2	1	21
28. Introduction to Chemistry and Physics	0	1	0	0	1
29. Introductory Inorganic Chemistry	0	0	2	0	2
30. Organic Chemistry	1	0	2	0	3
31. Principles of Chemistry	10	5	0	0	15
32. Principles of Chemistry for Engineers	1	0	0	0	1
33. Quantitative Analysis	4	1	2	0	7
34. Semimicroqualitative Analysis	2	1	3	0	6
35. Solution Chemistry	0	0	1	0	1
36. Special Topics in Chemistry	1	0	0	0	1
37. Structure and Bonding	1	0	0	0	1
38. Survey of Organic Chemistry	0	0	1	0	1
39. The Role of Chemistry in the Contemporary World	1	0	0	0	1
TOTAL	154	99	61	18	332

college chemistry course. Possible substitutes which were found included, "Fundamentals," "First-year College Chemistry," "Introductory Chemistry," or "Elementary Chemistry." The data in Table 7 reveal that institutions are using new titles (see Titles 1 through 3, 4 through 10, 12, 21 through 26, and 30 through 39) to describe their introductory college chemistry courses but few institutions are using the titles recommended by the Advisory Council on College Chemistry (see Titles 11, 13, and 27 through 29). The response to statement 15 in Table 7 disclose that the term "General Chemistry" still prevails as the most popular course name for first-year college chemistry.

Titles of Introductory College Chemistry Courses

An analysis of the data in Table 7 reflect the following subdivision in regard to course titles: 203 (61 per cent) of the courses were designated General Chemistry, 22 (6 per cent) were designated Inorganic Chemistry, 21 (6 per cent) were designated Introduction to Chemistry, and 15 (5 per cent) were designated Principles of Chemistry; the remaining 71 (22 per cent) included a total of 35 different course titles. The 212 institutions surveyed offer a total of 332 introductory college chemistry courses excluding the courses designed for non-science majors. The diversity of course titles depicted in Table 7 suggests that numerous changes are taking place in the introductory college chemistry curriculum. A summary of the responses to the request for a description of the introductory college chemistry course titles (see Table 7) reveal a variety of course titles and these various course descriptions imply that the introductory college chemistry course is in the midst of a revolution; the more popular title, however, is still "General Chemistry." Examination

TABLE 8. NUMBER AND PER CENT OF INTRODUCTORY COLLEGE CHEMISTRY COURSES OFFERED BY INSTITUTIONS AND STUDENT ENROLLMENT

Institutions	Total No. of Courses	Number and Per Cent of Courses: One Course		Two Courses		Three Courses		Four or More Courses	
		No.	%	No.	%	No.	%	No.	%
1. Universities	154	32	39	28	34	15	18	5	5
2. Liberal Arts	99	56	72	20	25	1	1	0	0
3. Junior Colleges	61	26	63	10	24	5	12	0	0
4. Specialized	18	7	58	4	33	1	8	0	0
Total	332	121		62		22		5	
Mean Per Cent			57		30		10		2

Institutions	Enrollment per Year	One Course	Two Courses	Three Courses	Four or More Courses
1. Universities[a]	0-100	2	0	0	0
	101-200	8	2	2	0
	201-300	3	8	1	0
	301-400	7	3	0	0
	401-500	3	3	0	0
	501-1000	5	7	2	0
	1001-2000	3	5	6	1
	2001-3000	1	0	4	3
	5000	0	0	0	1
2. Liberal Arts[b]	0-100	35	7	0	0
	101-200	13	8	0	0
	201-300	2	1	1	0
	301-400	3	1	0	0
	401-500	1	0	0	0
	501-1000	2	1	0	0
	1001-2000	0	0	0	0
	2001-3000	0	0	0	0
	5000	0	0	0	0
3. Junior Colleges[c]	0-100	16	4	0	0
	101-200	9	1	1	0
	201-300	0	0	0	0

TABLE 8. (Continued)

Institutions	Enrollment per Year	One Course	Two Courses	Three Courses	Four or More Courses
3. Junior Colleges (Continued)	301-400	1	2	2	0
	401-500	0	0	0	0
	501-1000	0	0	1	0
	1001-2000	0	0	1	0
	2001-3000	0	0	0	0
	5000	0	0	0	0
4. Specialized	0-100	3	1	0	0
	101-200	2	1	0	0
	201-300	1	0	0	0
	301-400	0	1	1	0
	401-500	0	0	0	0
	501-1000	1	1	0	0
	1001-2000	0	0	0	0
	2001-3000	0	0	0	0
	5000	0	0	0	0
All Institutions[d]	0-100	55	10	0	0
	101-200	32	12	3	0
	201-300	6	9	2	0
	301-400	11	7	3	0
	401-500	4	3	0	0
	501-1000	8	9	4	0
	1001-2000	3	5	7	1
	2001-3000	1	0	4	3
	5000	0	0	0	1
Total Number of Courses[e]		120	55	23	5

[a]Two university respondents listed the number of courses but failed to list the course enrollment.

[b]Two Liberal Arts respondents listed the number of courses offered but failed to list the course enrollment.

[c]Three junior college respondents listed the number of courses but neglected to list the course enrollment.

[d]Seven institutions failed to list the student enrollment.

[e]The total number of courses does not include the 29 courses from the seven institutions which failed to list the student enrollment for their respective institutions.

of the various course titles (Table 7, Course Title column, items 9, 16, 28, 32, and 39) also indicates some emphasis upon cooperation between disciplines in the introductory college chemistry course.

Courses Offered, Course Prerequisites,
and Student Preparation

The sum of the percentages listed in the Two Courses, Three Courses, and Four or More Courses columns in the Number and Per Cent of Courses part of Table 8, for each category of institutions responding, reveal the following data with reference to the different number of first-year college chemistry courses offered: 57 per cent of the universities, 26 per cent of the liberal arts colleges, 36 per cent of the junior colleges, and 41 per cent of the specialized institutions offer two or more introductory college chemistry courses. The data in Table 8 reveal the following contrast with respect to the number of introductory college chemistry course offerings. The general practice of the university classification is to offer more than one course (49 of 82 universities offer two or more courses), while the data in Table 8 the One Course column reveal that the majority of the liberal arts colleges (56 of 77), the junior colleges (26 of 41) and the specialized institutions (7 of 12) offer only one introductory college chemistry course which is specifically designed for science majors.

To determine if the number of courses offered in the institutions surveyed is a function of the number of students enrolled in the first year college chemistry course at a given institution, the data from the latter portion of Table 8 were plotted in Figures 1, 2, 3, 4 and 5. The plot of the number of different courses offered in the university category per year versus the student enrollment in their first-year college chemis-

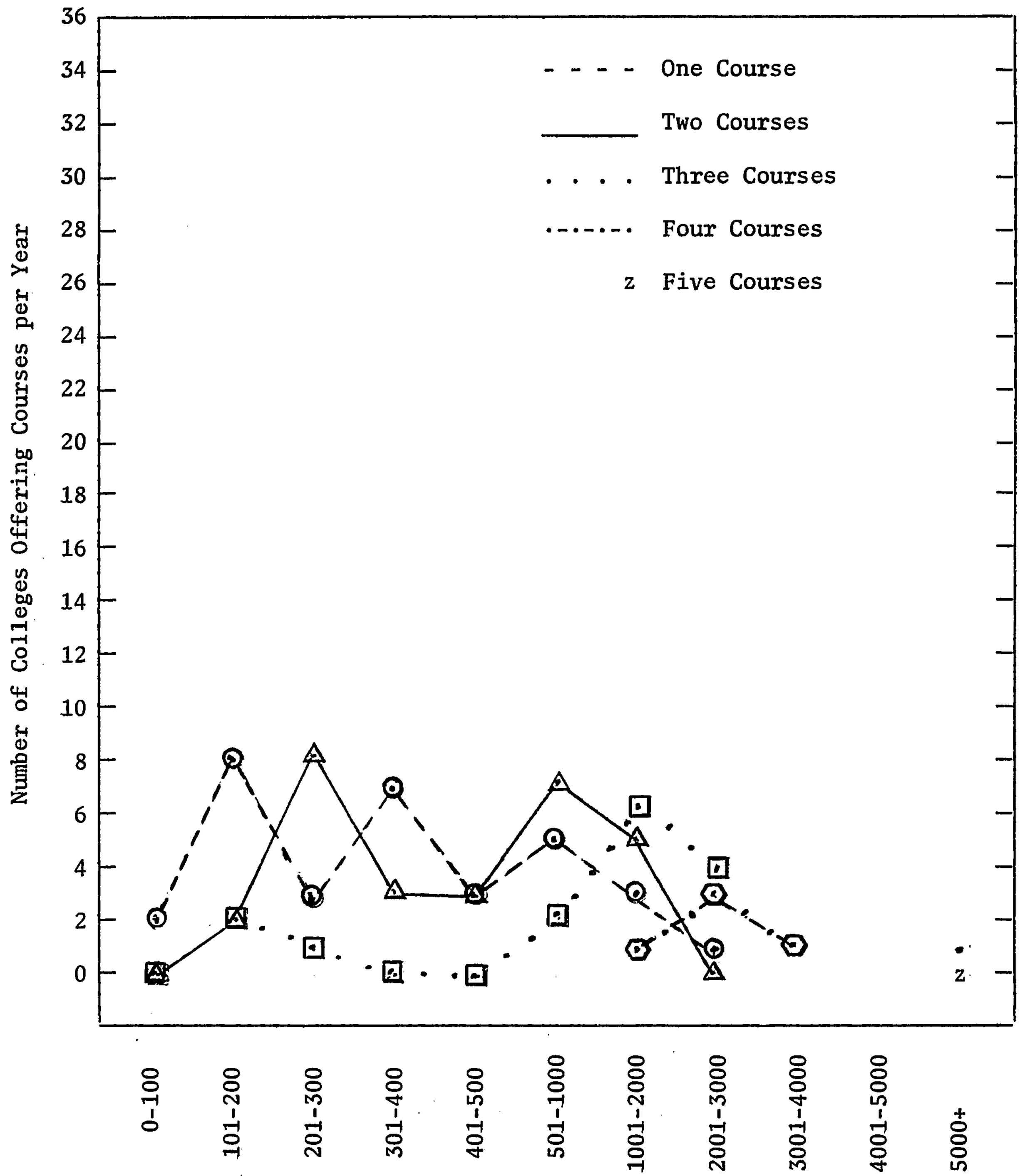

Figure 1. Comparison of the Number of Courses Offered per Year with the Student Enrollment in Introductory College Chemistry per Year in Universities.*

*Two of the eighty-two respondents listed the number of courses but did not list the enrollment.

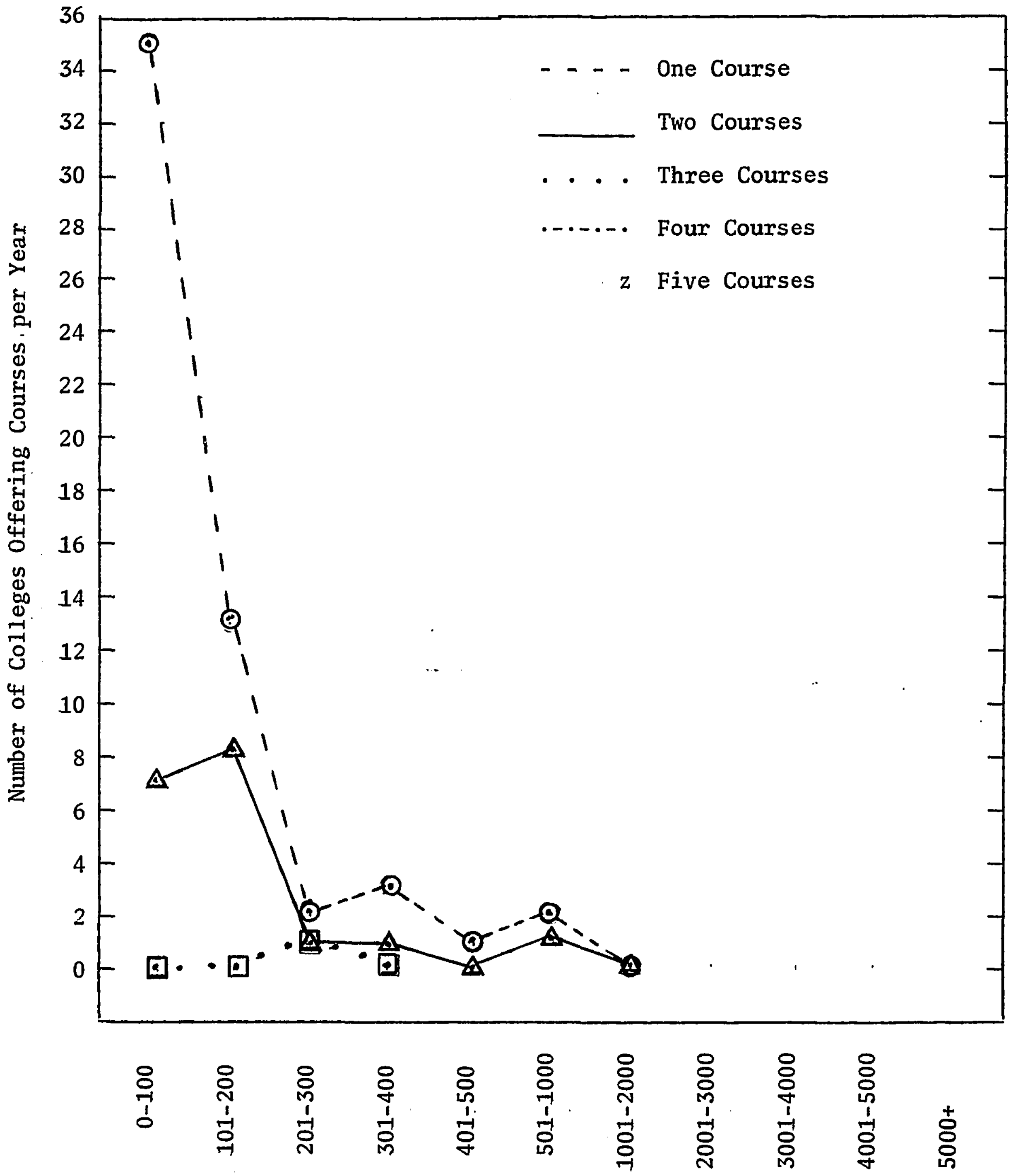

Figure 2. Comparison of the Number of Courses Offered per Year with the Student Enrollment in Introductory College Chemistry per Year in Liberal Arts Colleges.*

*Two of the seventy-seven respondents listed the number of courses but failed to list the course enrollment.

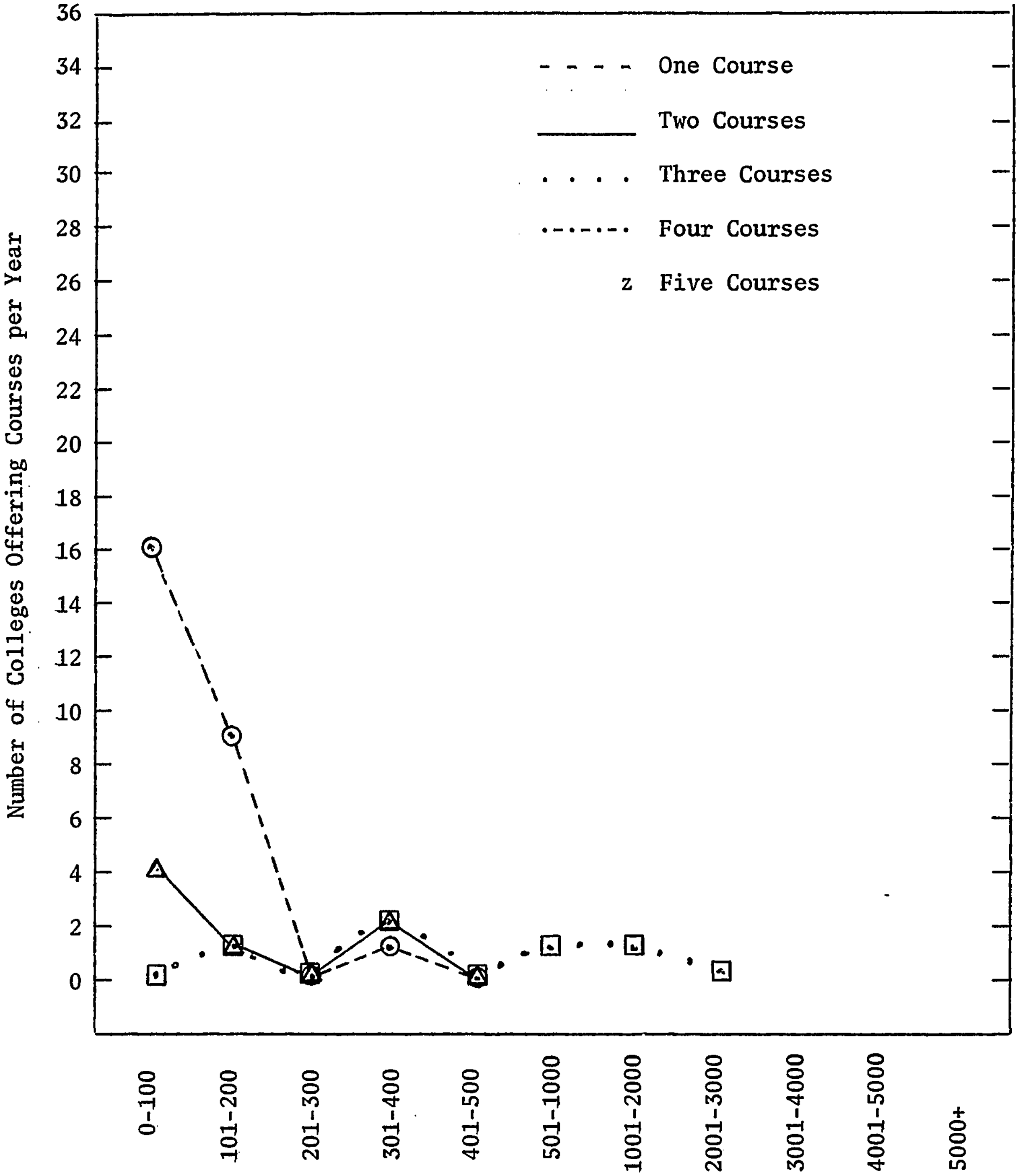

Figure 3. Comparison of the Number of Courses Offered per Year with the Student Enrollment in Introductory College Chemistry per Year in Junior Colleges.*

*Three of the forty-one respondents listed the number of courses but did not list the course enrollment.

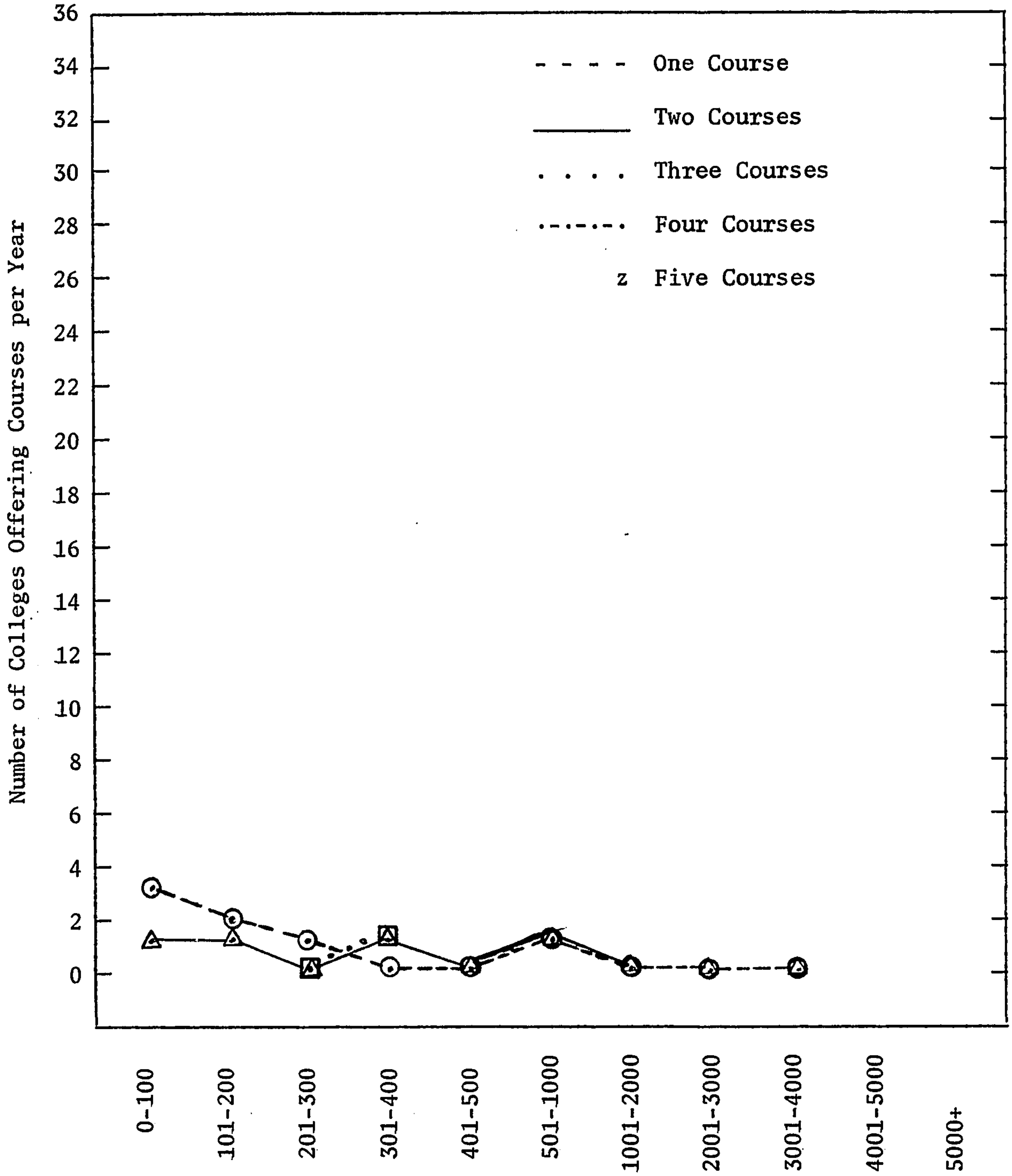

Figure 4. Comparison of the Number of Courses Offered per Year with the Student Enrollment in Introductory College Chemistry per Year in Specialized Institutions.

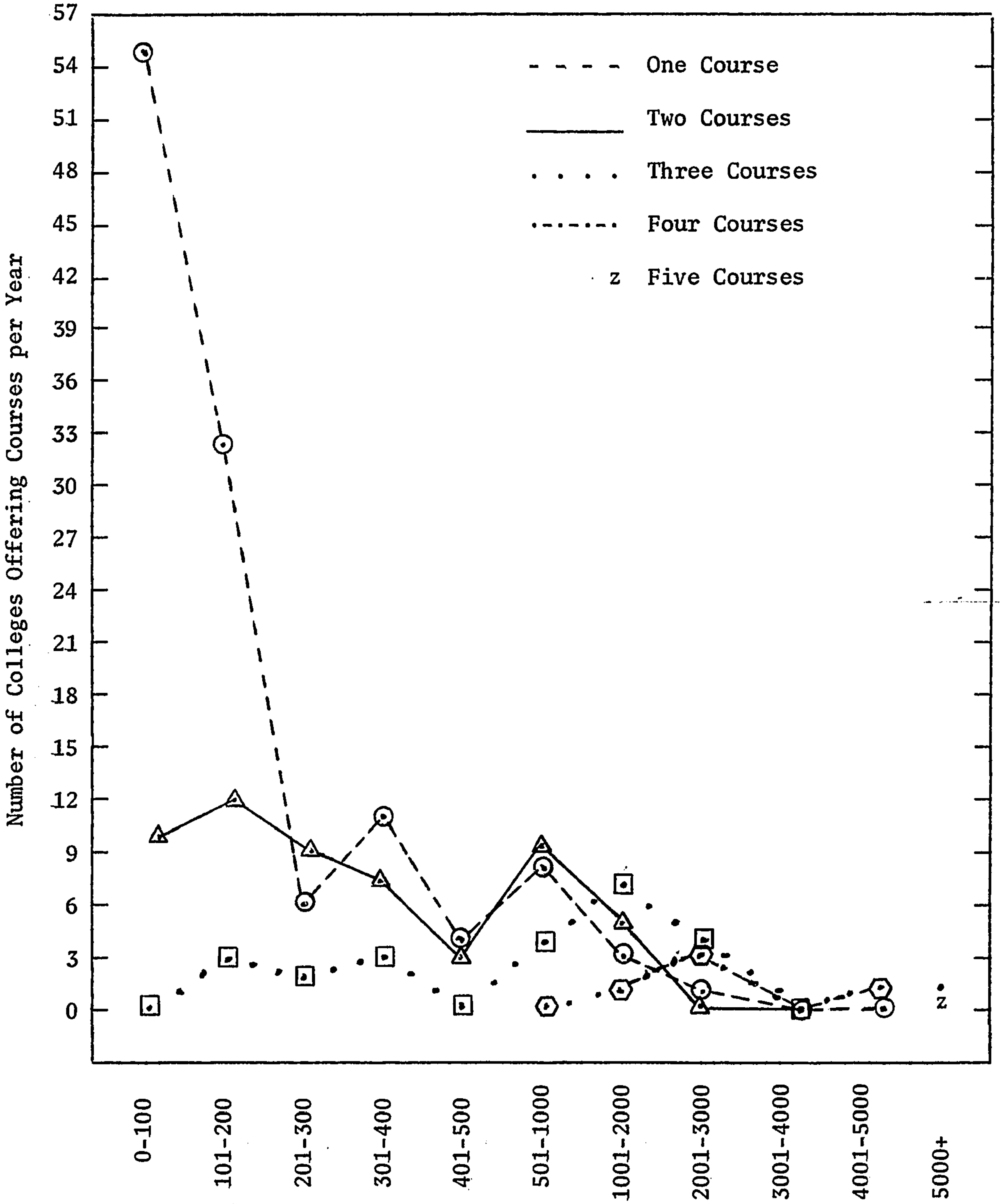

Figure 5. Comparison of the Number of Courses Offered per Year with the Student Enrollment in Introductory College Chemistry per Year in all Responding Institutions.*

*Seven of the 212 respondents did not list course enrollments.

try courses (Figure 1) reveal that the number of different courses offered is directly related to student enrollment especially when the enrollments exceeds 500. Similar data plots were made for the liberal arts colleges (Figure 2), junior colleges (Figure 3) and specialized institutions (Figure 4) and these diagrams fail to show a corresponding relationship between the number of courses offered and student enrollment. The graphs in Figures 2, 3 and 4 indicate an almost equal offering of one and two courses per institution in these three categories when the student enrollment exceeds 200. Larger enrollments in these three categories, in general, do not show a corresponding increase in the number of courses offered. When a comparison of the number of courses offered per year in all institutions surveyed is made with the total student enrollment (Figure 5), the graph reveals that an increase in enrollment reflects a corresponding increase in course offerings when the enrollment exceeds 500. The data in Figures 1 through 5 suggest that the university category offers a greater number of different introductory college chemistry courses than the other college classifications.

The data in the first part of Table 8 (Total Number of Courses column) and Table 9 (Total column) disclose that 204 (332 courses from 212 institutions listed in Table 8 minus 128 courses which list no course prerequisites, statement 1, Table 9) of the 332 courses (61 per cent) offered in all institutions surveyed require specific but variegated prerequisites prior to enrollment in the introductory college chemistry course. Prerequisites were required by 101 (77 per cent) of the 154 university courses, 52 (53 per cent) of the 99 liberal arts courses, 42 (69 per cent) of the 61 junior college courses, and 9 (50 per cent) of the 18

TABLE 9. PREREQUISITES TO INTRODUCTORY COLLEGE CHEMISTRY COURSES

Prerequisites	Univ.	Lib. Arts	Junior Colleges	Spec. Inst.	Total
1. None	53	47	19	9	128
2. High School Preparation					
a. Mathematics (including algebra and trigonometry)	21[a]	16[a]	13[a]	3	53
b. Chemistry (one year)	41[b]	17	11[c]	1	70
c. Chemistry and Mathematics	1	1	1[e]	0	3
d. English	1	0	0	0	1
e. High School Science	1(3 yrs)	1(2 yrs)	0	0	2
f. Physics	3	0	2	1	6
g. Scholarship in High School Chemistry, Mathematics, and Physics	0	2	2	0	4
h. Upper 1/3 of class or honor	0	0	1	1	2
3. Examinations					
a. The American Council on Education Psychological Examination (ACB) (score 89% or greater)	1	0	0	0	1
b. American College Examination (ACE) (60 or better)	0	0	1	0	1
c. American Chemical Society (ACS) High School Examination	1	1	0	0	2
d. The American College Testing Program (ACT)	7[d]	1	0	0	8
e. Placement Test					
(1) Advanced	1	1	0	0	2
(2) Chemistry and Mathematics	1	1	0	0	2
(3) Mathematics	1	2	0	0	3
(4) Standardized	1	0	1	0	2
(5) Toledo Placement	0	1	1	0	2
f. College Entrance Examination Board (CEEB) Score (High)	1	0	0	0	1
g. Mat = 600[f]					
h. Predicted GPR-2 or better	1	0	0	0	1
i. School and College Ability Test (SCAT)	1	0	0	0	1
j. Scholastic Aptitude Test (SAT) (7500 or better)	1	0	0	0	1
4. College Preparation or Requirement					
a. College Algebra	1	4	2	0	7
b. Physics	0	0	1	0	1

TABLE 9. (Continued)

Prerequisites	Univ.	Lib. Arts	Junior Colleges	Spec. Inst.	Total
4. College Preparation or Requirement (Continued)					
c. Mathematics up to Calculus	2	0	0	0	2
d. Calculus Corequisite	1	1	0	0	2
e. Science Major	1	0	0	0	1
5. Other					
a. Instructor Approval	0	0	0	1	1
b. Invitation	1	0	0	0	1
c. Motivation and Achievement	1	0	0	0	1
d. Permission	1	2	0	0	3
e. Entrance Examination	4	1	1	1	7

[a]Requirements range from 1½ years to 4 years high school mathematics.

[b]Three universities require a grade of C or better; two specify a grade of B or better.

[c]One junior college requires a grade of B or better in high school chemistry; one requires 2 years high school chemistry; one requires a grade of C or better in high school chemistry.

[d]Four universities required the following minimum score on the ACT Examination: One - 25%; one - 26%; one - 89%; one - 90%.

[e]One junior college specified a C grade in high school chemistry and intermediate algebra.

[f]The respondent did not define nor describe this placement test.

specialized institution courses. Examination of the various prerequisite titles listed in Table 9 reveal the most popular of these prerequisites to be high school chemistry (Prerequisite 2-b) and/or high school mathematics (Prerequisite 2, items a and c), including algebra and trigonometry. That 128 of the 332 courses (39 per cent) offered in all institutions surveyed require no prerequisites raises several questions. Do all first year college students possess the academic preparation necessary for a successful experience in freshman college chemistry or does the chemistry professor assume all students qualified and proceed to disperse the facts and principles of chemistry?

An examination of the data in Table 10 (All Institutions column, items 2 and 3) reveal that when the students have had high school experience, it is largely that of a traditional course. The high school chemistry experience of students enrolled in freshman college chemistry is 68.2 per cent traditional and 14 per cent Chemical Bond Approach (CBA) or Chemical Education Materials Study (CHEMS); this suggests that a total of 82.2 per cent of the first-year college chemistry students have had a course in high school chemistry. An observation of the data in Table 10 (item 3) reveals that only one student in five with prior experience in high school chemistry has studied in one or more of the new secondary science innovations and reflects some doubt with respect to the alleged impact of these innovations on the college chemistry curriculum by showing disagreement and possibly refuting the statement made by R. J. Kokes, in 1964, when he remarked: "...the impact of CBA, CHEM, and PSSC courses is now being felt."[180]

The data in Table 9 (Prerequisite number 2, sum of items b and c in Total column) indicate that 73 of the 332 courses (22 per cent) offered list high school chemistry and/or high school chemistry and mathematics as a prerequisite requirement to freshman college chemistry, yet the data in Table 10 (sum of items 2 and 3 in All Institutions column) disclose that 82.2 per cent of the students enrolled in freshman college chemistry in all institutions surveyed have had previous experience in high-school chemistry.

---

[180]R. J. Kokes, "The Present Chemistry Curriculum at the John Hopkins University," Journal of Chemical Education, 41, (1964) p. 131.

How do these institutions justify their actions in either neglecting or rejecting the high-school chemistry experience as a bona fide prerequisite to first-year college chemistry? Does this imply that some institutions ignore the high school training of their students and proceed on the theory that all subject matter (first-year college chemistry) must be taught to all students regardless of what was done in high school? One university professor, in an additional comment attached to the questionnaire, probably reflects the opinion of some college professors by remarking:

> Students are inadequately prepared for college chemistry by virtue of weak background in English, mathematics, and physics. The vast majority of college students, were and are at other like institutions throughout the nation, have not been exposed to exceptionally good high school teaching. Thus, even if he has taken chemistry in high school, he often is at a disadvantage in having to unlearn misinformation. It is my honest conviction that the high school chemistry course should either be completely abandoned or turned over to college professors and high school teachers of like training and ability. If this latter were done, there would be little use for a general chemistry course in the college curriculum.

The fact that some institutions are showing evidences of recognizing the scholastic capability and academic preparation of high school graduates reveals a difference in opinion as to the value of high school chemistry. The challenge offered qualified students and capable students is reflected in the prerequisites listed in Table 9 (Prerequisite 3) and in the additional comments which the respondents attached to the questionnaire whereby a qualified student may enroll in an advanced first-year chemistry course or be promoted into an upper level chemistry course.

The variety in course offerings, as shown in Table 7 (items 16, 26 and 32), also disclose that some institutions are designing courses to meet the student's vocational aspirations. The data in Table 8 show a slight trend to this effect by revealing the following pattern with respect to the number of different introductory courses offered by the responding institutions: 34 per cent of the universities offer two courses, 18 per cent offer three courses, and 5 per cent offer four or more courses; 25 per cent of the liberal arts colleges offer two courses and 1 per cent offer three courses; 24 per cent of the junior colleges offer two courses and 12 per cent offer three courses; 33 per cent of the specialized institutions offer two courses and 8 per cent offer three courses. In summation, the data in Table 8 reveal that 30 per cent of all institutions surveyed offer two courses, 10 per cent offer three courses, and 2 per cent offer four or more courses. The graph in Figure 1 reveals a direct relationship between the number of courses offered in the university classification and the student enrollment by showing an offering of three or more introductory chemistry courses when the enrollment exceeds 500. Since the data in Table 8 (One Course column) indicate that 57 per cent of all institutions surveyed offer only one introductory college chemistry course, the investigator surmises the one course offering to be the general practice; however, the data do reveal a slight trend away from the practice of offering only one introductory college chemistry course for science majors.

Since, in 1966, only 3,107 bachelor degrees in chemistry were awarded out of a total of 555,613 bachelors degrees granted,[181] the indication in Table 10 (All Institutions column) that 10.1 per cent of all students who have previously passed freshman chemistry eventually major in chemistry is intriguing.

In summary, the various descriptions of prerequisites to first-year

---

[181]Gordon M. Barrow, "Dull Approach Leads to Fewer Graduates," _Chemical and Engineering News_, _46_, June 10, 1968, p. 65.

TABLE 10. PREVIOUS HIGH SCHOOL CHEMISTRY EXPERIENCE OF INTRODUCTORY COLLEGE CHEMISTRY STUDENTS AND PER CENT OF THESE STUDENTS WITH SUCCESSFUL ACADEMIC EXPERIENCE IN INTRODUCTORY COLLEGE CHEMISTRY WHO EVENTUALLY MAJOR IN CHEMISTRY

Academic Experience and Per Cent Chemistry Majors	Mean Per Cent of Students				
	Univ.	Lib. Arts	Junior Colleges	Spec. Inst.	All Inst.
High School Chemistry Experience:					
1. No chemistry	9.5	11.9	22.1	4.5	12.4
2. Traditional High School Chemistry	66.7	71.5	63.1	76.3	68.2
3. CHEM Study or CBA	14.3	11.5	17.6	16.4	14.0
Introductory college chemistry students who eventaully major in chemistry:					
4. Chemistry majors	8.9	11.9	10.1	7.5	10.1

college chemistry courses (see Table 9) and the corresponding assessment of the first-year college chemistry student's academic experience in high school chemistry (see Table 10) reveal a variety in required prerequisites. In addition, only 73 courses of a total offering of 332 courses list high school chemistry as a prerequisite yet 82.2 per cent of the students enrolled in freshman chemistry have had previous experience in high school chemistry. The available data also reveal a difference in opinion of college professors regarding the educational value of high school chemistry.

The diversity in course credit, as shown in Table 11, with respect to the number of semester hours credit per course, semester hours chemistry offered per college, and the total number of semester hours offered

TABLE 11. COURSE CREDIT IN INTRODUCTORY COLLEGE CHEMISTRY COURSES

Classification	Number of Semester Hour's Credit per Course Offered												
	2	3	$3\frac{1}{3}$	4	5	$5\frac{1}{3}$	6	$6\frac{2}{3}$	7	8	9	10	12
1. Universities	2	2	3	16	7	2	16	2	1	70	6	27	0
2. Liberal Arts	1	1	0	2	1	0	8	2	1	64	3	15	1
3. Jr. Colleges	0	4	0	5	3	3	3	3	1	18	2	19	0
4. Specialized	0	0	0	0	0	2	1	0	1	10	0	4	0
TOTAL	3	7	3	18	11	7	28	7	4	162	11	65	1

	Credit in Semester Hours per Course and per College			
	Total No. of Courses	Total No. of Semester Hrs.	Semester Hrs. per Course	Semester Hours per College
1. Universities	154	1130.0	7.40	13.8
2. Liberal Arts	99	787.3	7.85	10.2
3. Jr. Colleges	61	460.0	7.54	11.2
4. Specialized	18	143.7	8.00	12.0
TOTAL	332	2521.0		
MEAN	1.6	11.9	7.29	11.9

is almost as great as that previously shown in course titles and prerequisites. Credit in the first experience in college chemistry ranges from two to 12 semester hours credit per year, while the average number of semester hours reported per individual course in all institutions surveyed is 7.29 (2521 semester hours/332 courses). The average number of courses offered per institution per year is 1.6 and the mean semester hours credit reported in the total number of different introductory chemistry courses offered per institution per year is 11.9 (2521 semester hours/212 institutions). The data in 8 column in Table 11 show that the most popular schedule for the introductory college chemistry course per year is the eight semester hour course; the second choice being the ten semester hour course (162 of the 332 courses are offered for eight semester hours credit per year and 65 are offered for ten semester hours credit per year).

Academic Fields and Degrees of Chemistry Professors

The questionnaire requested the name of the professor in charge of the introductory college chemistry course, the highest degree held and the field in which it was earned. The request was also made that the number of other professors teaching introductory chemistry, lecture or laboratory sections, be indicated with the field of specialization and degree held by each.

The number of professors teaching introductory college chemistry courses, as shown in Table 12, refers to full-time and part-time professors. All professors so listed are understood to be teaching one or more lecture or laboratory sections in introductory college chemistry or to have duties in connection with the courses.

The data in Table 12, disclose that there are 459 professors teaching introductory college chemistry in 82 universities; 224 in 77 liberal arts colleges; 105 in 41 junior colleges; and 48 in 12 specialized institutions--a total of 836 professors in 212 institutions. This is an average of more than five professors per university, less than three for each liberal arts college, less than three for each junior college, and four for each specialized institution or a mean average of approximately four for the 212 participating institutions. Computing a statistical average

TABLE 12. ACADEMIC FIELD AND HIGHEST DEGREE EARNED BY PROFESSORS OF INTRODUCTORY COLLEGE CHEMISTRY

Field of Specialization and College Degree	Number of Professors				
	Univ.	Lib. Arts	Junior Colleges	Spec. Inst.	Number of Professors
Chemistry					
Bachelors	6	6	0	0	12
Masters	38	37	69	20	164
Doctorate	409	170	19	25	623
Chemistry Education					
Masters	0	0	2	2	4
Chemical Engineering					
Bachelors	1	0	0	0	1
Doctorate	0	1	1	0	2
Pharmaceutical Chemistry					
Doctorate	0	1	0	0	1
Science Education					
Masters	1	1	2	0	4
Doctorate	0	0	0	1	1
Education					
Bachelors	0	0	1	0	1
Masters	2	1	5	0	8
Doctorate	2	1	1	0	4
Biology					
Bachelors	0	0	1	0	1
Masters	0	2	1	0	3
Botany					
Masters	0	0	1	0	1
Zoology					
Masters	0	0	1	0	1
Clinical Pathology					
Masters	0	1	0	0	1
Pathology					
Doctorate	0	1	0	0	1
Horticulture					
Bachelors	0	0	1	0	1
Physics Education					
Masters	0	1	0	0	1
Pre-Medical					
Bachelors	0	1	0	0	1
TOTAL	459	224	105	48	836
AVERAGE NUMBER OF PROFESSORS PER COLLEGE	5.5	2.9	2.6	4.0	3.9

of the personnel involved in first-year chemistry is not possible because some institutions indicated a variety in number of instructors each year due to fluctuations in student enrollment. Approximately 89 per cent (409 out of 459) of the university professors have earned doctoral degrees in chemistry and 8 per cent (38 out of 459) have completed master degrees in chemistry. Similar information is shown for the other institutions (see Table 12).

TABLE 13. FIELD AND DEGREE OF PROFESSORS IN CHARGE OF INTRODUCTORY CHEMISTRY COURSE

Field and Degree	Univ.		Lib. Arts		Junior Colleges		Spec. Inst.		All Respondents	
	No.	%	No.	%	No.	%	No.	%	No.	%
Chemistry										
Bachelors	1	1	0	0	0	0	0	0	1	.5
Masters	4	5	14	18	29	71	3	25	50	24.0
Doctorate	77	94	59	77	1	2	6	50	143	67.0
Chemistry Education										
Masters	0	0	2	3	1	2	2	17	5	2.0
Education										
Bachelors	0	0	0	0	1	2	0	0	1	.5
Masters	0	0	0	0	4	10	0	0	4	2.0
Zoology										
Masters	0	0	0	0	1	2	0	0	1	.5
Horticulture										
Masters	0	0	0	0	1	2	0	0	1	.5
Science Education										
Masters	0	0	0	0	1	2	0	0	1	.5
Doctorate	0	0	0	0	0	0	1	8	1	.5
Pathology										
Doctorate	0	0	1	1	0	0	0	0	1	.5
Chemical Engineering										
Doctorate	0	0	0	0	1	2	0	0	1	.5
Botany										
Masters	0	0	0	0	1	2	0	0	1	.5
Biology										
Masters	0	0	1	1	0	0	0	0	1	.5

The data in Table 12, (Number of Professors column) reveal that the highest degree held by 12 (1.4 per cent) of the first-year chemistry professors from all participating institutions is a bachelors degree in chemistry and that 37 professors (4.4 per cent) have received their professional education in a field of specialization which requires a background in chemistry but is not the discipline chemistry per se. According to the data in Table 12 (Field and Degree column) the academic training of the first-year college chemistry professors is in 14 different fields of specialization, including chemistry, with 623 professors (Number of Professors column) out of a total of 836 (75 per cent) having earned a doctoral degree in the discipline of chemistry. A summary of the data in Table 12 (Number of Professors column) reflects the following distribution in regard to the various number of the different highest degrees held by the professors from all types of institutions teaching the introductory course in college chemistry: 17 bachelors degrees--12 in chemistry; 187 masters degrees--164 in chemistry and 632 doctoral degrees--623 in chemistry.

The data in Table 13, (All Respondents column) reveal that of the professors in charge of the first-year college chemistry courses, 67 per cent have earned the doctorate in chemistry, 0.5 per cent in science education, 0.5 per cent in pathology, and 0.5 per cent in chemical engineering (these latter three are related science fields); a total of 68.5 per cent. Of the 212 supervising college chemistry professors, 24 per cent have completed, as their highest academic degree, the masters degree in chemistry, 2.5 per cent in science education (a total of 26.5 per cent) while less than 9 per cent are educated in a science other than chemistry

TABLE 14. PROFESSIONAL TRAINING AND RESPONSIBILITIES OF STUDENT ASSISTANTS

	Number of Student Assistants				
	Univ.	L.A.	Jr. Coll.	S.I.	Total
<u>Degree</u>					
None	115	281	93	15	504
Bachelors	733	29	2	31	795
Masters	148	10	0	10	168
Doctorate	4	0	0	0	4
Other[a]	137	0	0	0	137
<u>Responsibility</u>					
1. Lecture	13	0	1	1	15
2. Laboratory setup or laboratory supervisor	1052	259	21	6	1338
3. Chemical preparation for lecture and/or laboratory	12	72	5	1	90
4. Stockroom	28	20	5	0	53
5. Grade papers, exams, report sheets or proctor exams	148	54	2	1	205
6. Cleanup	0	0	3	1	4
7. Recitation	322	9	0	2	333
8. Prepare and/or repair equipment	0	0	2	0	2
9. Tutor (help sessions, discussions)	74	0	1	0	75
10. Prelab or lecture demonstration	0	0	2	0	2
11. Conferences	27	0	0	0	27
12. Reading	0	1	0	0	1
13. Clerical (inventory, budget supply, order equipment)	0	0	1	0	1
14. Answer questions	0	0	1	0	1
15. Correct homework	0	12	0	0	12
Number of Assistants	1137	320	95	56	1608
Colleges indicating no assistants	6	10	9	5	30
Colleges with assistants	76	67	32	7	182
Range	0-70	0-30	0-6	0-29	0-70
Average per College	14.9	4.7	3.0	4.7	7.5

[a]Degree indicated but level not specified.

and education. The data in Tables 12 and 13 also show, like other surveys, a need for more professors with earned doctorates in chemistry or science education with a specialty in chemistry, especially in junior colleges. The number of graduate assistants who teach or assist in the teaching of the lecture phase of the first-year college chemistry course was not compiled in these statistics.

College professors need teaching assistants, and the lack of professional trained personnel has resulted in the utilization of student assistants (Table 14). The responsibilities allocated to student assistants (Table 14) are numerous. Of the 212 institutions surveyed, 182 (86 per cent) utilize the services of student assistants. The most popular use of student assistants is either in preparing for laboratory or as laboratory supervisors. Priorities two and three for student assistants include paper grading and conducting recitation sections respectively.

The data in Table 14 indicate the quantity and not the quality of the assistants. Since 504 out of 1,608 student assistants (31 per cent) have no college degrees and 795 (49 per cent) have only completed the bachelors degree (see Total column in Table 14), questions could probably be raised about the quality of the assistants. The investigator believes those instructing both lecture and laboratory should be well educated, however, the limited supply of well educated personnel now and in the forseeable future indicates the need to utilize student assistants for routine tasks such as paper grading and routine laboratory work.

CHAPTER V

THE INTRODUCTORY COLLEGE CHEMISTRY COURSES OFFERED AT THE ACCREDITED INSTITUTIONS

The participating professors in the survey were requested by the investigator to describe the typical introductory college chemistry courses offered to their students by either checking a preselected list of responses supplied by the investigator or by providing their own descriptions in the space provided under the title "Other." The decision to use those first six preselected descriptions in Table 15 was dictated by the descriptions found in the literature search and by the recommendations of questionnaire validation committee. The respondents were invited to react to statements with reference to the utility of the currently available textbooks and laboratory manuals and, in addition, were asked questions to ascertain whether textbook changes, course revisions, laboratory exercise changes and/or revisions had occurred during the past two years. If such changes or modifications had recently occurred, the respondents were invited to respond to questions relative to statements concerning modification in course objectives with related course changes, to evaluate statements describing pedagogical practices with respect to the handling of course content, and to respond to questions requesting whether special tests or other measures had been prepared for evaluating student achievement in introductory college chemistry. The respondents

TABLE 15. TYPICAL INTRODUCTORY COLLEGE CHEMISTRY COURSES OFFERED

Type of Course	Univ.		Lib. Arts		Jr. Coll.		Spec. Inst.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
1. No distinction as to chemistry background. All students take same course.	42	51	49	63	28	68	7	58	126	59
2. Course is designed in such a way that the better prepared student can complete the equivalent of one year course in one semester.	11	13	7	9	3	7	2	16	23	10
3. Place all students together but compensate for the student who has had no prior study in chemistry by using some of the early laboratory periods as drill sessions to give students experience in nomenclature, elementary facts of atomic theory, and equation writing.	5	5	12	15	6	14	1	8	24	11
4. Selected students are given a brief review and then placed in an honors section by examination.	7	8	7	9	0	0	0	0	14	6
5. Offer several introductory chemistry courses of varying difficulty.	37	42	18	25	6	10	6	50	66	30
6. Give a sufficiently different course in the laboratory such that no student feels he is repeating the course. Try to eliminate trivia and introduce advanced and nontraditional topics.	22	26	34	44	7	17	1	8	64	30
7. Other (Supplied by Respondents)										
(a) Courses designed so that each student may attain to the utmost of his ability.	16	20	6	8	0	0	0	0	22	10
(b) Teach no lab first semester; 6 hours per week in second semester using analytical balances, etc.	1	1	0	0	0	0	0	0	1	0
(c) Organic.	1	1	0	0	0	0	0	0	1	0
(d) Special curricula (nurses, environmental health, and home economics) take special courses during third quarter of general course--others continue study of general chemistry.	1	1	0	0	0	0	0	0	1	0
(e) A course in chemical principles with a minimum of descriptive math.	1	1	0	0	0	0	0	0	1	0

TABLE 15. (Continued)

Type of Course	Univ. No.	Univ. %	Lib. Arts No.	Lib. Arts %	Jr. Coll. No.	Jr. Coll. %	Spec. Inst. No.	Spec. Inst. %	All Inst. No.	All Inst. %
7. Other (continued)										
(f) Offer special problems course for weaker students.	0	0	0	0	1	2	0	0	1	0
(g) Some students take the non-science major course and then enter the science major course.	0	0	0	0	1	2	0	0	1	0
(h) Programmed materials are used with weaker students.	0	0	0	0	1	2	0	0	1	0
(i) Course designed to challenge students.	0	0	0	0	6	14	0	0	6	3
(j) One course for science majors and another for non-science majors.	0	0	1	1	0	0	1	8	2	1
(k) Students are placed in a difficult course by examination.	0	0	1	1	0	0	0	0	1	0

were also invited to react to statements with reference to general college chemistry laboratory operations; particularly, information on prelaboratory sessions and methods of data collecting and recording; questions were also asked to determine the nature and use of special laboratory projects. In addition, a description of the methods used to challenge superior students with previous high school chemistry experience was also requested. Respondents were also invited to state what they felt the introductory course in college chemistry should be.

Typical Introductory Chemistry Courses

The 59 per cent response to item 1 in Table 15 (Total column) reveals that a majority of the institutions in the sample returns pays no attention to the high school chemistry background of the incoming freshman chemistry student and the general practice was to place all students in the same first-year college chemistry course. The observation (item 5 in Table 15) that 42 per cent of the universities, 25 per cent of the liberal arts colleges, 10 per cent of the junior colleges, and 50 per cent of the specialized institutions offered several courses of varying difficulty, reflects a difference in opinion of chemistry educators with respect to course offerings designed to meet the needs of students with varied academic backgrounds and capabilities. Close examination of the findings in the Total column of Table 15 also disclose that some of the institutions are providing additional innovations to challenge students with varied academic background and ability. Those practices are: (1) the institutions offer a course which is sufficiently different from the high school chemistry course in the laboratory phase so that no student feels he is repeating the course (30 per cent response to item 6), (2) the institutions

TABLE 16. PERCENT OF TEACHER REACTIONS TO STATEMENTS CONCERNING THE CONVENTIONAL COURSE IN COLLEGE CHEMISTRY

The "conventional" course in college chemistry:	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	A[a]	D[b]	U[c]	A	D	U	A	D	U	A	D	U	A	D	U
1. is generally satisfactory for all students.	26	58	9	40	40	15	29	48	19	50	41	8	33	49	13
2. is more appropriate for students who major in chemistry than those who do not.	37	48	10	38	27	18	56	34	4	33	50	16	41	41	12
3. could be significantly modified for the superior student with a good high school background in science and mathematics by eliminating descriptive matter and introducing more advanced non-traditional topics.	53	36	6	57	29	7	69	19	9	66	16	16	58	29	8
4. needs new textbooks of varying difficulty but adhering to traditional topics stressing the products of chemistry.	18	52	21	14	46	29	21	41	29	25	41	33	17	47	26
5. should be taught from textbooks of varying difficulty but utilizing the inquiry approach, i.e., stressing the processes of chemistry.	41	18	30	53	11	27	58	9	26	41	25	25	49	14	28
6. will continue because the time and cost are essential factors which have tended to retard the introduction of chemistry innovations analagous to CBA and CHEM study at the introductory college level.	34	34	23	28	35	23	31	34	21	8	50	41	30	35	24

[a]A - Agree [b]D - Disagree [c]U - Uncertain

design courses in which the student may achieve to the utmost of his capabilities (10 per cent response to item 7-a), (3) a course is designed in such a way that the better prepared student can complete the equivalent of one year course in one semester (10 per cent reply to item 2) and (4) selected students are given a brief review and then placed in an honors selection by examination (6 per cent response to item 4).

A comparison of the findings listed in Tables 15 and 16 reveals incongruity between teacher practices in general college chemistry and teacher reactions to statements describing the introductory college chemistry course. Confirmation of the above mentioned inconsistency is revealed by the fact that 59 per cent of the participating respondents ignored the high school chemistry background of students and placed all students in the same course, while 33 per cent of those respondents (statement 1, Table 16) agreed that the present first-year college chemistry course was generally satisfactory for all students. That equal number of respondents (41 per cent responded to statement 2, Table 16) agree and disagree that the present introductory college chemistry course taught at their respective institutions was most appropriate for the chemistry major, while 12 per cent remained uncertain, also reveals conflicting views as to the applicability of the present first-year college chemistry course. Such indecision was not evident in the junior colleges with respect to statement 2 in Table 16, since 56 per cent of these educators gave an affirmative response; an indication of a majority agreement that the current first-year college chemistry course is more appropriate for the chemistry major. The 58 per cent response to statement 3, All Institutions column, Table 16, reveal that the respondents favor the practice of modifying the first-year college chemistry course designed for students with a good academic background in high school science and mathematics by eliminating some descriptive subject matter and introducing advance non-traditional topics.

TABLE 16-A. T-TEST OF SIGNIFICANCE FOR TEACHER REACTIONS TO STATEMENTS CONCERNING THE UTILITY OF GENERAL COLLEGE CHEMISTRY

Topic	Groups of Institutions Compared					
	J. C. vs. Spec.	L. A. vs. Spec.	Univ. vs. Spec.	Univ. vs. J. C.	Univ. vs. L. A.	L. A. vs. J. C.
Degrees of Freedom	51	87	92	121	157	116
	t-test scores					
Statement (See Table 16)	(1)	(2)	(3)	(4)	(5)	(6)
1	1.091	0.380	0.679	0.875	0.474	1.177
2	1.952	0.566	0.685	2.202*	0.044	1.965
3	0.555	0.429	0.227	0.652	0.441	0.266
4	0.531	0.392	0.748	0.221	0.625	0.268
5	0.254	0.268	0.090	0.573	0.695	0.005
6	2.233*	2.187*	2.207*	0.338	0.206	0.157

*Significant at the 5 per cent level of confidence.

To determine whether a statistically significant difference exists in the professor reactions between the various college categories with respect to the statement, "The conventional course in college chemistry is more appropriate for the students who major in chemistry than those who do not," the data were subjected to the t-test. A t-test score of 1.98 in column four in Table 16-A would show a significant difference at the 5 per cent level of confidence. The resulting t-test score of 2.202 in Table 16-A (Column 4) shows the following difference with respect to professor responses to the above statement: The junior college professors believe the present introductory college chemistry course is more appropriate for the students who major in chemistry than those who do not when compared with the university professors. The t-test scores reveal the remaining three classifications with respect to the above statement were in mutual disagreement.

The t-test scores for item 6 in Table 16-A Columns 1, 2, and 3 are 2.233, 2.187, and 2.207. Those t-test scores indicate, at the 5 per cent level of confidence, that junior college, liberal arts, and university professors believe the traditional course in general college chemistry will continue as is because time and cost are essential factors which have tended to retard the introduction of innovations analagous to the Chemical Bond Approach and Chemical Education Materials Study, whereas specialized institutions tend to believe otherwise. With respect to the remaining four statements, the t-test scores reveal that those four classifications were in mutual agreement.

Approximately one half (49 per cent response to item 5, Table 16) of all respondents agreed that the freshman chemistry course should be taught from textbooks of varying difficulty and utilizing the inquiry approach while 28 per cent remained uncertain in their decision. A closer examination of the data, with respect to individual categories, (see Table 16, item 5) indicates consensus by some professors since 58 per cent of the junior colleges and 53 per cent of the liberal arts professors agreed on the use of textbooks of varying difficulty utilizing the inquiry approach.

TABLE 17. TEACHER OPINIONS ON WHAT THE INTRODUCTORY COURSE IN COLLEGE CHEMISTRY SHOULD BE

Opinions	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
1. A course in chemical principles with descriptive chemistry serving only to illustrate these concepts.	56	68	50	64	28	68	9	75	143	67
2. A course based heavily on laboratory and classroom demonstration of a phenomenon.	4	4	2	2	5	12	0	0	11	5
3. An integrated course in physics, chemistry, and mathematics.	4	4	8	10	5	12	1	8	18	8
4. An inventory of factual materials and phenomenological formulas needed for advanced study.	1	1	2	2	1	2	0	0	4	1
5. Other (Supplied by Respondents)										
(a) Choice (1) with a course in chemical principles with a sizeable amount of descriptive chemistry--more than just enough to illustrate principles--enough to show the principles are valid and to give the student an appreciation for the wide applications of chemistry in many areas.	1	1	0	0	0	0	0	0	1	0
(b) Choice (1) with a balance between principles and descriptive materials. Students must learn chemical reactions sometime.	2	2	0	0	0	0	1	8	3	1
(c) Chemical principles and descriptive chemistry along with adequate laboratory.	2	2	0	0	0	0	0	0	2	0
(d) Combination of (1) and (2) above, equivalent amounts of each.	1	1	1	1	1	2	0	0	3	1
(e) Basic principles, historical background for perspective emphasis on scientific method, relevance to common experience.	1	1	0	0	0	0	0	0	1	0
(f) A course in chemical principles heavily endowed with phenomena observed in the laboratory and text to illustrate these principles. Integration with math is necessary to illustrate and utilize transfer of ideas. Descriptive chemistry MUST be brought back to show how principles are derived.	1	1	0	0	0	0	0	0	1	0

TABLE 17. (Continued)

Opinions	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
5. Other (continued)										
(g) Choice (1) with enough descriptive chemistry to count.	1	1	2	2	0	0	0	0	3	1
(h) Almost Choice (1) but add separate sections on descriptive chemistry.	1	1	0	0	0	0	0	0	1	0
(i) 3/5 of Choice (1) and 2/5 of Choice (2).	1	1	0	0	0	0	0	0	1	0
(j) Choice (1) but include organic and biochemistry in descriptive.	1	1	0	0	0	0	0	0	1	0
(k) Choice (1) but add problem solving emphasis.	1	1	0	0	1	2	0	0	2	0
(l) Our course is an "introduction to a scientific lab" in which students learn to make precise measurements with first class equipment. The specific skills learned are considered secondary. The lecture portion of the course is heavily based on principles and descriptive chemistry illustrates the concepts. This is impossible to teach without an introduction to some physics and math also. However, our students all take introductory calculus and the majority also take physics.	1	1	0	0	0	0	0	0	1	0
(m) All of the above. Stay in the middle as far as you can and as far as the student can.	0	0	0	0	1	2	0	0	1	0
(n) A modification of Choice (1). Basic chemical principles are highly essential and require enough descriptive chemistry to make these principles workable and desirable. Mathematical problems to illustrate or make the principles workable should certainly be stressed—especially those dealing with chemical equilibria and the mole concept.	0	0	0	0	1	2	0	0	1	0
(o) Limited principles followed by vigorous inorganic.	0	0	0	0	0	0	1	8	1	0
(p) Chemical principles with considerable descriptive chemistry of the elements serving as a supplement and illustration.	0	0	1	1	0	0	0	0	1	0

TABLE 17. (Continued)

Opinions	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
5. Other (continued)										
(q) Choice (1) but present an experimental basis for chemical theory, not to treat descriptive material as simply illustrated of "principles."	0	0	1	1	0	0	0	0	1	0
(r) Lecture or in Choice (1) but lab should be almost exclusively qualitative in approach stressing physical properties, stochiometry, and structure.	0	0	1	1	0	0	0	0	1	0
(s) A course in chemical principles and properties, with the descriptive parts of the course used both to illustrate principles as the principles are taught and as illustrative of the principles when certain elements or types of compounds are discussed.	0	0	1	1	0	0	0	0	1	0
(t) A course in chemical principles with strong laboratory emphasis on descriptive and qualitative analysis (1st semester) and quantitative (including pH and electrochemistry) in 2nd semester.	0	0	2	2	0	0	0	0	2	0
(u) Choice (1) modified· some descriptive chemistry (even applications to industry) are of intrinsic value in addition to possible illustration of principles.	0	0	1	1	0	0	0	0	1	0

When the participating professors were asked to either check statements or to provide a description as to what they felt that the introductory course in college chemistry should be, the ensuing responses were multitudinous (Table 17). Examination of the data in Table 17 (item 1, All Institutions column), however, disclose that a majority of the introductory college chemistry professors prefer a course in chemical principles with descriptive chemistry serving only to illustrate these concepts; the response ranged from a low of 64 per cent in the liberal arts colleges to a high of 75 per cent in specialized institutions, with an average acceptance of 67 per cent for all institutions surveyed.

The respondents attached additional comments to Part II, Section 17 of the Questionnaire and those comments reveal that some of the chemistry professors are concerned about course content currently being offered in their introductory college chemistry courses. Inherent was the plea to return to descriptive chemistry; 16 of the 21 additional comments requested an inclusion of more descriptive materials into the first-year college chemistry course. Several comments stressed the point that the present introductory course be improved. One professor remarked, "Descriptive chemistry _must be brought back_ to show how principles are derived." Another professor wrote: "These 'descriptive topics' are being sadly omitted from curriculums in many 'progressive' schools." The investigator believes that there was general agreement and consensus of a sufficient majority of the responding professors (Table 17, item 1) to suggest that an introductory course be offered in _chemical principles and properties with descriptive parts of the course used both to illustrate principles and to show how principles are derived._

TABLE 18. DESCRIPTION OF LABORATORY MANUAL OR TEXTBOOK CURRENTLY USED IN INTRODUCTORY COLLEGE CHEMISTRY

Description	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
1. Staff prepared materials	12	14	13	16	0	0	2	16	27	12
2. Commercially prepared materials[a]	24	29	23	29	6	14	4	33	57	26
3. Combination of (1) and (2)[b]	46	56	42	54	35	83	6	50	127	60
4. Most of these are unsatisfying	0	0	1	1	0	0	0	0	1	0

[a]One respondent chooses paperbacks over hard bounds.

[b]The respondents listed the following variations in combination of staff and commercially prepared materials:

1. Choice (2) except laboratory manual is supplemented and textbook is supplemented by handouts.

2. Choice (2) plus ditto experiment sheets.

3. Choices (1) and (2) plus Scientific American Offprints.

Other comments revealed that a few institutions are offering special problem courses for weaker students and are also providing educational materials to assist these students. One institution offers a remedial course for students who have not had high school chemistry; however, any student may take this two semester hour course along with the regular course.

Description of Laboratory Manual and Textbook

An examination of the findings in Table 18 (All Institutions column, item 3) reveals that 60 per cent of all respondents (a possible acceptance) used a combination of staff prepared and commercially prepared materials for both lecture and laboratory. The findings revealed 56 per cent of the universities, 54 per cent of the liberal arts colleges, 50 per cent of the specialized institutions and 83 per cent of the junior colleges used a combination of staff and commercially prepared materials. The "other" category is not shown in Table 18, but those additional comments disclosed that one professor had written his own textbook, and two others had written their own laboratory manuals.

TABLE 19. NUMBER AND PERCENTAGE OF INSTITUTIONS INDICATING COURSE REVISIONS AND/OR NEW COURSE ADDITIONS

Type of Change	Univ.		Lib. Arts		Junior Colleges		Spec. Inst.		Total No. of Changes	
	No.	%	No.	%	No.	%	No.	%	No.	%
1. New course or revision	26	31	20	25	11	26	4	33	61	28
2. Text or laboratory exercise change or revision	66	80	65	84	33	80	10	83	174	82

Course Revisions and/or Course Additions

The twelve questions in Section 16, Part I of the Questionnaire were formulated to obtain evidence concerning practices utilized in new courses designed primarily for the specializing science student. The data in Table 19 show that 28 per cent (Total column, item 1) of the responding institutions have added a new course or revised their present course. The majority (Table 19, Total column, item 2) of the college chemistry professors indicated displeasure with the current laboratory manuals and/or textbooks. Those data demonstrate that four out of five professors have made textbook and laboratory exercise changes during the past two years while three out of ten have either made course revisions or added new courses.

Of the institutions reporting change, 60 per cent reported that the content and program of instruction have been considerably modified but the framework (course outline) of the old course retained (Table 20, item 1). That evidence suggests that few sweeping course changes have been made; change seems to be either a modification of the existing course or textbook and/or laboratory exercise changes. Occasionally both modification of the existing course and introduction of a new course take place. Seldom was the old course completely replaced by a new course.

While 58 per cent of the professors rely mainly upon a single textbook and laboratory manual in the new or revised course (item 2, Table 20), 27 per cent expect more outside readings in the new or revised course than they did in former courses (item 5, Table 20). Forty-eight per cent of the instructors are using outlines or syllabi which were prepared especially for the new course (item 3, Table 20) yet less than half (42 per cent response to item 9, Table 20) of the respondents have formulated

TABLE 20. PERCENTAGE OF TEACHER RESPONSES TO QUESTIONS RELATING TO COURSE AND TEXTBOOK CHANGES

Types of Changes	Percentage of Institutions Responding														
	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	Y[a]	N[b]	U[c]	Y	N	U	Y	N	U	Y	N	U	Y	N	U
1. Have the content and program of instruction been considerably modified but the framework of the old course retained?	56	40	3	66	29	3	63	34	2	41	41	17	60	35	3
2. Do you rely mainly upon a single textbook and laboratory manual in the new or revised course?	62	36	1	57	40	2	56	41	2	50	50	0	58	39	1
3. Are you using an outline or syllabus which was prepared especially for the new course?	47	50	2	54	44	1	36	63	0	50	41	8	48	50	1
4. Does the new course attempt to treat much of the traditional content such as the study of gases, liquids, solids, etc. as separate units?	46	43	9	48	45	6	60	36	2	41	58	0	49	43	6
5. Do you expect more reading outside the text in the new or revised course than in the old course?	19	75	4	29	64	5	43	48	7	16	75	8	27	66	5
6. Is the work in the new or revised course independent of collaboration with physicists?	75	24	0	66	32	1	48	43	7	33	67	0	64	33	1

TABLE 20. (Continued)

Types of Changes	Universities Y	N	U	Liberal Arts Y	N	U	Jr. Colleges Y	N	U	Specialized Y	N	U	All Inst. Y	N	U
	Percentage of Institutions Responding														
7. In the new or revised course has your department prepared a list of independent studies or research requiring investigations which can be carried on by the individual student outside the classroom and/or laboratory?	6	92	1	5	93	1	14	85	0	16	83	0	8	91	0
8. Has your department prepared special tests or other means of evaluating student achievement of the distinctive aims for the new or revised course?	13	84	2	22	76	1	26	68	4	25	75	0	19	77	2
9. Does your new and/or revised course have a set of objectives which have been formally stated and to which all members teaching the course have access?	32	63	3	42	51	5	56	41	2	58	41	0	42	52	3
10. Do the objectives of the new and/or revised course differ substantially from the objectives of the older course?	28	65	5	31	66	2	31	58	9	33	67	0	30	64	4

[a]Y - Yes

[b]N - No

[c]U - Uncertain

a set of formally stated course objectives which was made available to all instructors. Only 30 per cent of those professors (item 10, Table 20) reported the new course objectives to be significantly different from those formally stated in the revised or replaced course. About 49 per cent (item 4, Table 20) of the respondents attempted to cover the traditional content such as the study of gases, liquids, and solids as separate units.

The response to question six in Table 20 (Is the work in the new or revised course independent of collaboration with physicists?) furnished evidence to show that new multi-diversity chemistry courses, especially the course which combines chemistry with other physical science courses, were offered by 33 per cent of the responding colleges.

The response to the Questionnaire seems to indicate that little use (8 per cent reply to item 7 in Table 20) was made of the student's time outside the regular scheduled classroom and laboratory for investigation of problems. The need for adequate testing in the new or revised course was suggested by the fact that only 19 per cent (item 8, Table 20) of the respondents indicated that special tests or other means of evaluating student achievement had been prepared.

The additional comments from individual professors, which were attached to the Questionnaire returns, indicated a dissatisfaction with the present introductory course. Thirty professors wrote notes in the Questionnaire margins; four enclosed personal letters and eight of those professors indicated that they were experimenting with various textbooks, including paperback supplements. Some of the professors remarked that they have yet to find a textbook they can agree is a satisfactory book. Other professors suggested a struggle with the course content especially in their attempts to answer questions related to such tasks as to the amount of descriptive work to include and whether or not to include thermodynamics. One professor had this to say regarding the status of the introductory college chemistry course:

> I'm retiring early because I've lost after 40 years all confidence in my judgment as to what to teach, how to do it, how much to expect of students, what performance deserves a passing grade. I'm too old to start over and recent years have produced increasing dissatisfaction with my work. I've kept on because recent staff and additions have seemed to have less competency than my own, but finally--I've had it... This is not a criticism of administration, or criticism against our school. I've given up because my self-respect won't permit me to continue with the present frustrations.

Another professor added: "The lab manual is supplemented and the text is bad and is supplemented by handouts written by the instructor." The foregoing two comments are indicative of the state of teaching in first year college teaching. At one extreme is complete frustration and at the other is the time consuming and monumental task of a professor writing his own material. The trend, however, is to do a limited number of experiments having a quantitative background and a small amount of descriptive work.[182]

The ensuing discussion revealed differences between the college categories with respect to course changes. The per cent response is in terms of the 174 respondents (item 2, Table 19) in the survey who indicated textbook changes and/or revisions. Three classifications of institutions (the exception is the specialized institution) in Table 20, (item 1) indicated that the content and program of instruction in general chemistry had been considerably modified but the outline of the former course retained.

---

[182]Edward L. Haenisch, Editor. The Content of Introductory College Chemistry, p. 21.

TABLE 20-A. T-TEST OF SIGNIFICANCE FOR STATEMENTS CONCERNING TEXTBOOK CHANGES

Topic	J. C. vs. Spec.	L. A. vs. Spec.	Univ. vs. Spec.	Univ. vs. J. C.	Univ. vs. L. A.	L. A. vs. J. C.
Degree of Freedom	51	87	92	121	157	116
Statements Concerning Textbook Changes (See Table 20)	(1)	(2)	(3)	(4)	(5)	(6)
1	0.703	0.406	0.922	0.332	1.152	0.655
2	0.610	0.732	0.922	0.366	0.275	0.129
3	1.699	0.589	0.808	1.552	0.548	2.061*
4	1.373	1.031	1.217	0.000	0.477	0.423
5	1.184	0.368	0.150	2.376*	1.026	1.549
6	1.509	2.292*	3.074*	1.255	0.917	0.513
7	0.166	0.868	0.785	0.945	0.145	1.062
8	0.624	0.022	0.479	1.911	0.878	1.204
9	0.147	0.276	1.039	1.932	1.403	0.684
10	0.837	0.182	0.414	0.771	0.536	1.296

*Significant at the 5 per cent level of confidence.

The data in Table 20 (All Institutions column, item 2) disclose that 58 per cent of the professors making textbook changes still rely mainly upon a single textbook and laboratory manual. That 48 per cent of all respondents gave an affirmative reply to the question asked to determine whether a course outline or syllabus had been prepared for the new introductory course (see Table 20, statement 3), suggests that approximately one half of the participating professors have either rejected or do not have time to prepare a course outline or syllabus. The implication is that the course authority is the textbook. The liberal arts and specialized institution professors, however, did indicate a possible acceptance of the responsibility of preparing a syllabus or course outline as evidenced by the 54 and 50 per cent affirmative response to item 3 in Table 20, respectively.

To determine if a statistically significant difference existed between the different categories with respect to the question concerning the use of an outline or syllabus specifically prepared for a new course, the t-test of 2.061 (Table 20-A, column 6, item 3) shows that, at the 5 per cent level of confidence, more liberal arts professors assume the responsibility of preparing course syllabi than do junior college professors.

The implication from the data in Table 20 (All Institutions column, statement 4) is a possible trend with respect to the teaching of the traditional topics of gases, liquids, and solids under a single topic rather than the traditional practice of teaching these topics separately and individually. The junior college professors conversely indicated a possible practice of teaching these units separately, as evidenced by a 60 per cent affirmative reply to statement 4 in Table 20.

The 66 per cent negative reply to statement 5 in Table 20 shows that the professors from all institutions surveyed rejected the assignment of more outside reading in the new course as compared to the reading required in the course which was replaced or with the former textbook. Although outside reading is not a typical practice, the t-test score of 2.376 in Table 20-A, column 4, however, reveals that a significant larger number of junior college professors than university professors, at the 5 per cent level of confidence, expected more reading in the new or revised course than in the course which was replaced. Although AC_3[183] recommended that

---

[183]Haenisch, "Content of Introductory College Chemistry," p. 21.

efforts be made to stimulate the preparation of a series of outlines (paperbacks for teaching at the first-year college level dealing with some important topics not adequately treated) and although some of those topics have been published by the Journal of Chemical Education and several major publishing companies, the above data infer little use of these reading materials.

The 67 per cent negative reply with respect to question 6 in Table 20 "Is the work in the new or revised course independent of collaboration with physicists?" suggests that the only college classification indicating a collaboration with physicists in the preparation of a new course or in the selection of a new textbook is the specialized institution. The t-test scores of 2.292 and 3.074 in Table 20-A, columns 2 and 3, supply statistical evidence, at the 5 per cent level of confidence, to support this practice of the junior college professors to seek assistance of physicists in the preparation of a new course while the liberal arts and universities tend to do otherwise.

The 19 per cent and 42 per cent affirmative reply to statements 8 and 9 in Table 20 (All Institutions column), indicated that all institutions rejected both the practice of stating course objectives and the responsibility of preparing special tests or other methods to evaluate whether these objectives had been achieved. Of the 42 per cent that accepted the responsibility of providing a set of formally stated objectives (Table 20, All Institutions column, item 9) less than half (statement 8 in Table 20 shows a 19 per cent response) have established methods to ascertain achievement of goals. The 56 per cent and 58 per cent affirmative responses to statement 9 in Table 20, however, indicated a possible acceptance of the responsibility of stating goals by junior colleges and specialized institutions. Less than half of these professors, however, have designed methods to evaluate attainment of these stated goals as evidenced by a 26 and 25 per cent affirmative reply to statement 8 in Table 20. With respect to statements 1, 2, 4, 7, 8, 9, and 10 in Table 20, the t-tests reveal the four classifications were in mutual agreement.

The investigator believes that the way to future progress still seems to lie in more thought on the part of college professors about goals and purposes. The data in Table 20 (statement 9) reveal that the majority of the junior college and specialized institution professors have stated objectives and, since a large number of these institutions' students transfer to liberal arts colleges and universities, logic seems to dictate that these latter institutions of higher learning need to state goals. The survey data also reflect another pedagogical contrast; i.e., although course changes have been made, the previously stated course objectives have been changed very little, if any, as evidenced by a 64 per cent negative reply to the question, "Do the objectives of the new and/or revised course differ substantially from the objectives of the older course?"

Pre-Laboratory Instruction

The Advisory Council on College Chemistry believes that pre-laboratory instruction is essential to a successful laboratory program and might replace the usual detailed laboratory instructions.[184] Time should be made

---

[184]Modern Teaching Aids for College Chemistry. Los Angeles, California: Advisory Council on College Chemistry, 1966, pp. 1-7.

available for a student to try to solve an experimental problem, discover an error in the procedure or judgment, and then try again. The Advisory Council on College Chemistry has developed and discussed the feasibility of using television tapes, film loops, and computer-assisted instruction (CAI) to supplement lecture and laboratory.[185] Some excellent television tapes and film loops are available which illustrate specific laboratory techniques or provide visual instructions for operating or understanding the principles of specific instruments. Films are also available which present the student with experimental data which he can then interpret and which permit him to draw conclusions. In addition, pre-labs are excellent for illustrating safety precautions, experimental design discussion, and experimental technique descriptions.

Use of Pre-Laboratory Instruction

The data in Table 21 disclose that the typical pre-laboratory, other than leaving the responsibility up to the student himself, revolves around the instructor dispensing information to the student. The four most generally accepted pre-laboratory types of instruction, as evidenced by a 69, 76, 77, and 83 per cent indicated usage (All Institutions column, Table 21), in the ascending order from least favored to more favored, are: (1) special emphases and different points are elucidated (item 11), (2) the theoretical basis of the experiment is discussed (item 9), (3) questions are answered (item 10), and (4) procedure is discussed (item 8). A total of 26 Types of Instruction including 15 under the choice Other were discussed.

The t-test score of 2.953 in Table 21-A, statement 7 and the t-test

[185]Ibid., p. 11.

TABLE 21. TYPE OF PRE-LABORATORY INSTRUCTION GIVEN TO INTRODUCTORY COLLEGE CHEMISTRY STUDENTS

Types of Instruction	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
1. Students are expected to have read directions.	73	89	72	93	38	92	11	91	194	91
2. Students are assigned supplementary readings other than laboratory manual directions.	9	10	11	14	9	21	3	25	32	15
3. A pre-laboratory drill assures that students have read directions.	16	19	9	11	7	17	2	16	34	16
4. A pre-laboratory quiz assures that students have read directions.	16	19	13	16	5	12	3	25	37	17
5. A pre-laboratory quiz assures that students have read supplementary readings.	1	1	1	1	0	0	0	0	2	0
6. A pre-laboratory quiz assures that students have worked the drill.	1	1	2	2	2	4	0	0	5	2
7. The experiment is demonstrated.	4	4	7	9	9	21	0	0	20	9
8. Procedure is discussed.	64	78	71	92	32	78	11	91	178	83
9. The theoretical basis of the experiment is discussed.	57	69	64	83	32	78	10	83	163	76
10. Questions are answered.	59	71	64	83	32	78	10	83	165	77
11. Special emphases and different points are elucidated.	55	67	55	71	29	70	9	75	148	69
12. Other (Supplied by Respondents)										
(a) Preliminary exercises are filled out by students prior to coming to lab.	1	1	0	0	0	0	0	0	1	0
(b) Preliminary questionnaire is filled out by student before lab (at his convenience) to assure that students have read directions.	1	1	0	0	0	0	0	0	1	0
(c) Students are given exams (written) after completion of experiment.	2	2	0	0	0	0	0	0	2	0
(d) Instructions vary—depend on type and difficulty of experiment.	1	1	0	0	0	0	0	0	1	0
(e) Experimental set-ups with emphasis on safety are shown.	1	1	0	0	0	0	0	0	1	0
(f) Experiment outlined in lab notebook prior to formal lab.	0	0	1	1	0	0	0	0	1	0
(g) Student must write a detailed procedure in lab notebook before coming to lab.	0	0	1	1	0	0	0	0	1	0

TABLE 21. (Continued)

Types of Instruction	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
12. Other (continued)										
(h) Safety precautions are given.	0	0	2	2	1	2	0	0	3	1
(i) Theory is covered in lecture in advance of lab work.	0	0	1	1	0	0	0	0	1	0
(j) Do not believe in pre-labs.	0	0	1	1	0	0	0	0	1	0
(k) Occasional pre-lab quiz.	0	0	0	0	1	2	0	0	1	0
(l) Combination of choices (a) and (c).	0	0	0	0	1	2	0	0	1	0
(m) The student works from directions he has formulated from manual and supplementary readings.	0	0	0	0	1	2	0	0	1	0
(n) Enough is discussed so that purpose is clear and technique understood.	0	0	0	0	1	2	0	0	1	0
(o) TV tapes covering equipment and setup shown last 5 minutes of class prior to lab.	0	0	0	0	0	0	1	8	1	0

TABLE 21-A. T-TEST OF SIGNIFICANCE FOR PRE-LABORATORY INSTRUCTION

Topic	J. C. vs. Spec.	L. A. vs. Spec.	Univ. vs. Spec.	Univ. vs. J. C.	Univ. vs. L. A.	L. A. vs. J. C.
Degrees of Freedom	51	87	92	121	157	116
Pre-Lab Instruction (See Table 21)	(1)	(2)	(3)	(4)	(5)	(6)
1	0.113	0.231	0.272	0.636	0.987	0.167
2	0.213	0.929	1.339	1.613	0.622	1.043
3	0.032	0.476	0.229	0.323	1.345	0.802
4	1.057	0.666	0.433	1.005	0.424	0.664
5	0.000	0.390	0.378	0.701	0.044	0.723
6	0.760	0.556	0.378	1.225	0.044	0.641
7	1.780	1.076	0.771	2.953*	1.037	1.939
8	1.035	0.063	1.083	0.000	2.511*	2.204*
9	0.383	0.018	0.974	0.986	2.011*	0.663
10	0.383	0.018	0.820	0.716	1.675	0.663
11	0.278	0.250	0.540	0.405	0.588	0.078
12	0.654	0.083	0.153	1.355	0.142	1.406

*Significant at the 5 per cent level of confidence.

scores of 2.511 and 2.204 (statement 8) and 2.011 (statement 9) show, at the 5 per cent level of confidence, the following differences in prelaboratory instructional procedures between the different college classifications: (1) the junior colleges place more emphasis upon demonstrations as a prelaboratory procedure when compared with universities, (2) the liberal arts colleges favored more discussion on procedure and the theoretical basis of the experiment when compared with universities (3) a similar significant difference was noted between the liberal arts colleges and junior colleges, in favor of the liberal arts colleges, in regard to statement 8 of Table 21 (the discussion of procedure). With respect to items

1, 2, 3, 4, 5, 6, 10, 11, and 12, the four classifications were in mutual agreement.

One professor directed attention to the use of television tapes covering equipment and set up prior to laboratory work. Only one respondent indicated the use of television tapes, while none indicated the use of film loops, yet these educational aids have been specifically designed and recommended by AC_3. The answer is probably reflected in that the use of television tapes for pre-labs came considerably before the formation of AC_3 and is probably only superior to demonstration where large numbers are involved unless students are able to review the tapes independently. One college professor in the survey also cautioned:

> Visual aids are overemphasized. They are good but tend to oversimplify.

These remarks tend to explain the low usage of audiovisual media in prelaboratory instruction.

Procedures for Handling Experimental Data

The spirit of science cannot be imparted by words alone since the nature of a scientific enterprise is shown most clearly by carefully thought-out laboratory work. In order for laboratory work to be successful, an experiment must be meaningful and data must be collected and interpreted. "Data are the information which is derived from an experiment or observation."[186] In order for data to be interpreted, data must be available for inspection and this necessitates instruction in the proper use of recording data. According to the Advisory Council on College

---

[186] John W. Renner and William B. Ragan. Teaching Sciences in the Elementary School. New York: Harper and Row, 1968, p. 163.

TABLE 22. PROCEDURES USED BY INTRODUCTORY CHEMISTRY STUDENTS FOR HANDLING EXPERIMENTAL DATA

Handling Procedures	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
1. Data are recorded in duplicate by use of carbon paper.	7	8	3	3	2	4	2	16	14	6
2. Data are recorded on blank separate sheets.	7	8	13	16	8	20	1	8	28	13
3. Data are recorded in blank notebooks.	34	41	36	46	14	34	3	25	87	41
4. Data are recorded on special printed forms you provide separately.	10	12	9	11	6	14	2	16	27	12
5. Other (supplied by respondents)										
(a) Data are recorded in space provided in laboratory manual.	17[a]	21	11	14	6	15	4	33	38	18
(b) General formal laboratory reports are required of students each year. The rest of the time, data are handed in on 3" x 5" cards.	0	0	2	3	0	0	0	0	2	0
(c) Qualitative analysis data are recorded in student notebooks.	0	0	1	1	0	0	0	0	1	0
(d) Data sheets are signed by the instructor who keeps one copy for later reference.	0	0	0	0	1	2	0	0	1	0
(e) Special report is written and turned in for grading.	0	0	0	0	1	2	0	0	1	0

[a]One respondent indicated a departure from standard manual soon.

Chemistry, "fill-in-the-blank" reports are much less valuable than keeping a notebook or journal, or writing reports in the style of articles presented in scientific publications.[187] Procedures used by the different institutions as to the methods by which their students handle data (Table 22) show a great deal of variability. There is no one best way of handling all types of data. The nine different methods listed show that the most typical method, as indicated by a 41, 46, 34, and 25 per cent response to item 3 in Table 22 by universities, liberal arts colleges, junior colleges, and specialized institutions, in the order listed, is to have students record data in blank notebooks. The 41 per cent response by all institutions indicates some adherence to this practice by college professors. The data in Table 22, item 5-a show that 18 per cent of all institutions surveyed still allow students to record data in the spaces provided in the laboratory manual--the old cook book may be obsolete, but it is still being used.

Recording of Laboratory Data

The most important function of a laboratory report is to focus the student's attention on the interpretation of data and the significance of results obtained. Many of the new experiments are designed to permit real freedom of thought on the part of the student and can be written up in project form.[188] The purpose, procedure, experimental data (in a form designed by the student), conclusion, and, most important, an analysis of results can be written in concise form. Students need the experience of

[187]Haenisch, "Experimental Curricula in Chemistry," pp. 21-22.

[188]A project form is a research-type report which is prepared individually by the student and patterned after a research notebook.

making interpretations of data, instead of having professors make interpretations for them. The first prerequisite for providing this experience in data interpretation, however, is keeping accurate and complete records.

There is no question that grading of the project-type of report is time consuming. The project-type (research-type) of report can help to develop the student's report writing ability and lends itself well to the type of experiments and reporting which require some creative thinking on the part of the student. Perhaps the logical answer to the time consuming evaluation of the research type report is a reasonable student-per-instructor ratio or an increase in the number of capable, qualified student assistants. A compromise between using other methods of reporting in part of the first course and the report written in the research manner in other parts of the course, allows both more lengthy experiments to be undertaken and experiences to be gained in report writing as well.

Type of Reporting Expected by Institutions in the Survey

The 61 per cent response to statement 1 in the All Institutions column in Table 23 shows the most typical type of data reporting that college professors expect from the first-year college chemistry students is to have them fill-in-data and results on printed sheets. An equialent number of professors expect graphs as evidenced by the data (statement 8) and the third preference is full calculations (a 51 per cent positive response to item 5). The 42 per cent response to statement 7 also reveals that some of the respondents request students to answer supplementary questions on printed sheets. The 66 per cent response to statement 2 in Table 23 indicates that the specialized institution is the only classification to accept the practice of allowing students to design report sheets. The 16 per cent use of full essay reports (item 3) by all institutions (the junior colleges show a high of 29 per cent) indicate a rejection of the recommendation of the Advisory Council on College Chemistry for research-type reports.[189]

The investigator suggests that any first-year chemistry course consists of a series of compromises. One such compromise is between the time the student spends in experimentation, calculation, interpretation, and report writing. Methods which shorten the time spent on report writing provide more time for the other activities. Some such compromises are necessary, but they should not be utilized completely. Some experiments should be written by the research-type report method.

The examination of the data in Table 23 reveals a total of 26 different methods that professors in all institutions surveyed declare that students use to record data. What do these findings imply? Are there really this many ways of recording experimental data which are educational beneficial to the student?

Other suggestions were also offered in additional comments by the respondents and several practices were suggested. Two of these practices required students to keep data notebooks and to duplicate raw data sheets for evaluation by laboratory instructor.

Challenging the Superior Student

The failure of a college to challenge the fraction of each freshman class that is superior is a luxury that society and colleges cannot

---

[189]"Instruction in General Chemistry and Expanding Student Population," p. 11.

TABLE 23. TYPE OF REPORTING EXPECTED FROM INTRODUCTORY CHEMISTRY STUDENTS

Type of Report	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
1. Fill in data and results on printed sheets.	60	73	42	54	23	55	4	33	129	61
2. Students design their own report sheets.	22	26	26	33	10	24	8	66	66	31
3. Full reports (essay form).	10	12	11	14	12	29	3	25	36	16
4. Sample calculations only.	19	23	28	36	10	24	3	25	60	28
5. Full calculations.	43	52	37	48	22	53	7	58	109	51
6. Duplicate raw data sheets (carbon paper record).	7	8	3	3	3	7	4	33	17	8
7. Supplementary questions are answered in the laboratory.	31	37	38	49	14	34	7	58	90	42
8. Graphs from data in the laboratory.	48	58	49	63	28	68	5	41	130	61
9. Other (supplied by respondents)										
(a) Combinations of several methods are used (depends on nature of experiment.)	0	0	2	2	0	0	0	0	2	1
(b) Result only on report sheet. Data and calculations checked in lab notebooks.	0	0	1	1	0	0	0	0	1	0
(c) Students write up the experimental results in proper scientific manner.	0	0	2	2	1	2	0	0	3	1
(d) Students keep notebooks for data, observation, calculations, and a paragraph for conclusions.	8	10	4	5	0	0	0	0	12	6
(e) Full report (3) plus assigned questions (essay).	0	0	2	2	0	0	0	0	2	1
(f) Answer sheets in lab manual including questions.	1	1	2	2	0	0	0	0	3	1
(g) Many questions on examinations are based on lab work.	0	0	1	1	0	0	0	0	1	0
(h) Signed raw data sheets.	0	0	0	0	0	0	1	8	1	0

TABLE 23. (Continued)

Type of Report	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
9. Other (supplied by respondents)(continued)										
(i) Full report taken from lab notes.	0	0	0	0	1	2	0	0	1	0
(j) Sometimes the student designs own report sheet.	0	0	1	1	1	2	0	0	2	1
(k) Outline form in notebook.	0	0	0	0	1	2	0	0	1	0
(l) Full report (sometimes).	0	0	0	0	1	2	0	0	1	0
(m) Report Cards.	0	0	0	0	1	2	0	0	1	0
(n) Unknown and unknown analysis.[1]	0	0	2	2	0	0	0	0	2	1
(o) Students have one week to complete report from data collected in lab.	0	0	0	0	1	2	0	0	1	0
(p) Reactions and equations.	1	1	0	0	0	0	0	0	1	0
(q) Write complete reports in style of journal articles.	1	1	0	0	0	0	0	0	1	0
(r) Discussions on various selected aspects of the experiment (outside class).	1	1	0	0	0	0	0	0	1	0

[1]Individual students or a small group of students are each assigned a different aspect of a problem (e.g., different temperatures and concentrations are assigned in a note study). Perhaps the best unknowns are open-ended experiments.

afford. Not to require the best efforts of the better students in order that the average students can "get by" is an injustice to both groups of students and our collective future. At least four types of programs for the superior students are now in use: (1) honors courses, (2) seminars, (3) advanced placement, and (4) independent study.

A small percentage of all institutions surveyed, in addition to the honors course, are using independent study, conference study, advanced placement, special projects, and several other methods to challenge superior students. The nature of these challenges is shown in the tabulations of Table 24 (Parts B, C, D, E, and F). Many reasons were given for not specifically designing courses to challenge the superior student. Part A of Table 24 gives 17 reasons for the inability of cooperating institutions to provide a challenge to superior students, the more popular one being the lack of professor time. One respondent believes there is no such thing as "superior" students or "special" talent; in fact he stated that the well-prepared, capable student is a myth. In contrast to this opinion, however, some colleges are providing a variety of methods to challenge superior or talented students. One such method was the placement of students by examination in the second semester of the first-year course or in an upper level chemistry course. One professor took issue with the provision of a challenge to high ability students by stating, "Our work is demanding enough to challenge the best. We do not introduce research to freshmen. We do not regard this as advisable or sound education."

Type of Honors Courses Offered

The findings in Table 25 shows that 41 colleges offer honors courses

TABLE 24. CHALLENGES TO SUPERIOR STUDENTS

Type of Course Offered	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
A. No provisions made, because										
1. No interest.	2	2	1	1	4	9	0	0	7	3
2. Lack of student time.	12	14	15	19	8	19	2	16	37	17
3. Lack of professor time.	17	20	23	29	13	31	3	23	56	26
4. Lack of facilities.	9	11	8	10	8	19	4	33	29	14
5. Do not have, but are interested.	11	13	25	32	10	24	3	23	49	23
6. Other (supplied by respondents)										
a. Lack of opportunity to become involved in undergraduate research.	1	1	0	0	0	0	0	0	1	0
b. High school chemistry is a very "elastic" course and no definite measure of achievement is evident in many cases.	1	1	0	0	0	0	0	0	1	0
c. Keep the regular course at a level of difficulty that even the superior students are challenged.	5	6	5	6	0	0	0	0	10	5
d. Present an interesting, honest course.	1	1	0	0	0	0	0	0	1	0
e. Offer more than one introductory course.	1	1	0	0	0	0	1	8	2	1
f. Few students of that caliber.	1	1	0	0	3	7	0	0	4	2
g. There is no such thing as "superior" students or "special" talent.	0	0	0	0	1	2	0	0	1	0
h. Special sections and assignments.	1	1	0	0	0	0	0	0	1	0
i. Few students want additional study.	1	1	1	1	0	0	0	0	2	1
j. Freshmen are very busy and the regular course is demanding.	1	1	0	0	0	0	0	0	1	0
k. Students are not good enough to handle additional independent work.	2	2	0	0	1	2	0	0	3	1

TABLE 24. (Continued)

Type of Course Offered	Univ. No.	Univ. %	Lib. Arts No.	Lib. Arts %	Jr. Coll. No.	Jr. Coll. %	Spec. No.	Spec. %	All Inst. No.	All Inst. %
6. Other (supplied by respondents) (Continued)										
1. Do not introduce research to freshmen; do not regard this as advisable or sound education.	0	0	1	1	0	0	0	0	1	0
Totals	15	18	7	9	5	12	1	8	28	13
B. Independent Study: (The student carries on a study of basic research under the direction of a faculty member and prepares a paper on his work in the manner of a journal article). The nature of this independent study is:										
1. Special laboratory project.	18	21	13	16	7	17	2	16	40	18
2. Special problem in qualitative analysis.	1	1	8	10	1	2	1	8	11	5
3. Special problem selected by the individual student.	8	9	6	7	8	20	2	16	24	11
4. Special problem selected by the chemistry department.	6	7	9	11	2	4	2	16	19	8
5. Do not have, but are interested.	12	14	16	20	12	29	3	25	43	20
6. No interest.	3	3	5	6	1	2	0	0	9	4
7. Other (supplied by respondents)										
a. Challenge them to pace the class.	0	0	1	1	0	0	0	0	1	0
b. Small investigations.	0	0	1	1	0	0	0	0	1	0
c. Student may choose a more difficult experiment to illustrate a chemical principle.	0	0	1	1	0	0	0	0	1	0
d. Students are encouraged to pursue AC3 published experiments.	0	0	1	1	0	0	0	0	1	0
e. Separate course.	0	0	0	0	1	2	0	0	1	0

TABLE 24. (Continued)

Type of Course Offered	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
B. Independent Study: ((Continued)										
7. Other (supplied by respondents)										
f. Assist students with research projects and require writings.	0	0	0	0	1	2	0	0	1	0
g. ACS Essay Contest.	0	0	0	0	1	2	0	0	1	0
h. Student is given supplementary reading.	2	2	0	0	0	0	0	0	2	1
Totals	2	2	4	5	3	7	0	0	9	4
C. Conference Study or Conference Sessions: (Informal meetings on a variety of topics - freshman presentation).										
1. Seminar.	6	7	8	10	3	7	1	8	18	8
2. Assist professors or graduate students in preparing papers to be presented at seminars.	0	0	2	2	0	0	0	0	2	1
3. Other (supplied by respondents)										
a. Short report required or outside reading.	0	0	1	1	0	0	0	0	1	0
b. Problem sessions and seminars available.	0	0	1	1	0	0	0	0	1	0
c. Freshmen invited to regular junior-senior seminar.	1	1	2	2	0	0	0	0	3	1
d. Informal conferences - open for conferences at vacant periods.	0	0	2	2	0	0	0	0	2	1
e. Informal discussions with chemistry majors.	0	0	0	0	1	2	0	0	1	0
f. Experimenting with tutorial system for the top 5% - 1 hour conference each week. Use these students as tutor for all other students. A tutor is available (about 50 students) every day at several different hours to assist the weak students.	1	1	0	0	0	0	0	0	1	0

TABLE 24. (Continued)

Type of Course Offered	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
D. Advanced Placement										
1. Passing an exam equivalent to general chemistry "final" (oral and/or written).	7	9	0	0	2	5	0	0	9	4
2. Advanced Placement Exam.	4	4	3	4	4	9	1	8	12	6
3. CEEB Score.	3	4	0	0	0	0	0	0	3	1
4. ACS High School Exam. (Greater than 70%)	1	1	0	0	0	0	0	0	1	0
5. Entrance Exam Score.	2	2	0	0	0	0	0	0	2	1
6. Good Academic Background (high school).	5	6	0	0	0	0	0	0	5	2
7. Good Academic Background (college at end of 1st quarter or end of 1st semester).	0	0	0	0	1	2	1	8	2	1
8. SAT math, high school chemistry.	0	0	0	0	1	2	0	0	1	0
E. Special Projects										
1. Number	17	21	15	20	9	22	2	17	43	20
2. Percent Devoted to Project										
a. 1-4%	1	--	0	--	3	--	0	--	4	--
b. 5-8%	5	--	2	--	1	--	0	--	8	--
c. 9% or higher	11	--	13	--	5	--	2	--	31	--
F. Other Methods Used to Challenge Students (supplied by respondents)										
1. Avoid duplication with high school lab.	1	1	0	0	0	0	0	0	1	0
2. Talented students are taught to program chemical problems for computer and then run the programs.	1	1	0	0	0	0	0	0	1	0
3. Undergraduate research program is open to such freshmen; projects are individual and at least at master's level.	1	1	0	0	0	0	0	0	1	0

TABLE 24. (Continued)

Type of Course Offered	Univ. No.	Univ. %	Lib. Arts No.	Lib. Arts %	Jr. Coll. No.	Jr. Coll. %	Spec. No.	Spec. %	All Inst. No.	All Inst. %
F. Other Methods Used to Challenge Students (supplied by respondents) (Continued)										
4. Superior students are encouraged to do research on a regular problem of interest to a faculty member.	2	2	0	0	0	0	0	0	2	1
5. Assign students to paper grading and general assisting.	1	1	0	0	0	0	0	0	1	0
6. Pay student assistants in research labs sometimes on independent project.	1	1	0	0	0	0	0	0	1	0
7. Limited special projects.	1	1	0	0	0	0	0	0	1	0
8. Optional recitation sessions.	1	1	0	0	0	0	0	0	1	0
9. First semester laboratory is qualitative; second semester is quantitative.	1	1	0	0	0	0	0	0	1	0

TABLE 25. TYPE OF HONORS COURSES OFFERED

	Number of Institutions Responding				
	Univ.	Lib. Arts	Jr. Coll.	Spec.	All Inst.
A. Description of Courses					
1. One which omits descriptive inorganic and schematic scheme of analysis.	2	0	1	1	4
2. A one semester course followed by thermo-dynamics.	0	0	0	0	0
3. A course in chemical principles with descriptive chemistry.	10	3	2	0	15
4. A course comprising largely organic chemistry.	0	0	0	0	0
5. A combined chemistry-physics course.	1	0	0	1	2
6. A course in crystal structure.	0	0	0	0	0
7. Other (supplied by respondents)					
a. One year course plus quantitative analysis.	1	0	0	0	1
b. A one-credit, one semester course to fill in deficiencies, followed by qualitative and descriptive course.	1	0	0	0	1
c. A 2-quarter course sequence covering one year work in a regular course.	1	0	0	0	1
d. All topics covered in more depth and detail than in the regular course.	1	0	0	0	1
e. Advanced General and Kinetics and Thermodynamics, Mechanisms.	1	0	0	0	1
f. The regular course with a different labo-ratory and substitution material.	1	0	0	0	1
g. Chemical Principles (one semester).	1	0	1	0	2
h. Course in chemical principles with strong emphasis on thermodynamics and quantam chemistry; NO lab work.	0	0	0	1	1

TABLE 25. (Continued)

	Number of Institutions Responding				
	Univ.	Lib. Arts	Jr. Coll.	Spec.	All Inst.
7. Other (supplied by respondents) (continued)					
i. Largely elementary physical chemistry.	1	0	0	0	1
j. Principles, Descriptive, Inorganic and Quantitative Analysis.	1	0	0	0	1
k. A second semester course emphasizing equilibrium and thermodynamics.	1	1	0	0	2
l. A course in chemical principles with laboratory emphasis on analytical techniques.	1	0	1	0	2
m. Current Scientific Development.	0	0	1	0	1
n. A course in chemical principles with a lab consisting of qualitative analysis, biochemistry, and quantitative analysis.	0	1	0	0	1
o. Descriptive Chemical Research; Qualitative Analysis; Chemical Principles; Quantitative Analysis.	0	1	0	0	1
p. A course which integrates analytical chemistry and general inorganic chemistry.	0	1	0	0	1
q. A rigorous contact with general chemistry--quite mathematical.	0	1	0	0	1
Totals	11	5	3	1	20
B. Methods for Selecting Students					
1. Placement Examination.	7	1	2	1	11
2. College Board Examinations.	7	1	1	0	9
3. Special Examinations.	4	0	0	0	4
4. High School Science Background.	10	2	5	0	17

TABLE 25. (Continued)

	Number of Institutions Responding				
	Univ.	Lib. Arts	Jr. Coll.	Spec.	All Inst.
B. Methods for Selecting Students (continued)					
5. High School Record	10	3	5	0	18
6. American College Testing Program.	4	1	1	0	6
7. American Chemical Society Exam.	1	0	3	1	5
8. ACT Grade in Mathematics.	2	0	2	0	4
9. High School Chemistry Grade.	6	3	4	0	13
10. Other (supplied by respondents)					
a. Local test given after choice (1)	1	0	0	0	1
b. Special formula worked out by Vanderbilt Testing Service, based on ability in course.	1	0	0	0	1
c. Free choice of eligible students (student enthusiasm is vital to make program effective).	1	0	0	0	1
d. Must be enrolled in calculus course.	1	0	0	0	1
e. Vocational interest.	1	2	0	0	3
f. Interview.	1	0	0	0	1
g. Purely elective.	0	1	0	0	1
h. Placement exam in math and chemistry, prepared by the Department.	1	0	0	0	1
i. Chemistry majors and/or chemical engineers--few deleted by test.	2	2	0	0	4
j. First semester record in chemistry.	1	0	1	0	2
k. Standing in freshman math.	0	0	0	1	1
l. Two years of algebra.	0	0	1	0	1
m. Instructors select on basis of past performance of student.	0	1	1	0	2
Totals	61	17	26	3	109

TABLE 25. (Continued)

	Number of Institutions Responding				
	Univ.	Lib. Arts	Jr. Coll.	Spec.	All Inst.
C. Suitability of "available" textbooks					
1. Suitable textbooks and laboratory manuals are available.	12	0	5	0	17
2. None of the existing textbooks or laboratory manuals suit our purpose.	4	2	1	1	8
3. Other (supplied by respondents)					
a. Have written own textbook or lab manual.	3	2	0	0	5
b. Choose to deviate from lab manuals because of greater freedom of opportunity to test items for main course. Therefore, NO manual could omit for fit purposes.	1	0	0	0	1
c. Suitable text but no suitable manual.	3	1	0	1	5
d. Barely suitable text--no lab manual.	1	0	0	0	1
e. Suitable textbooks and paperbacks are available.	1	0	0	0	1
f. Develop lab experiments for second semester.	1	0	0	0	1
g. Would like a lab manual with more quantitative experiments.	1	0	0	0	1
h. Use three texts.	0	1	0	0	1
Total	27	6	6	2	41

with a minimum of 23 different course descriptions; the most popular course being one in chemical principles with descriptive chemistry. Part A of Table 25 shows the variety of courses offered; the inference from these data is that a single honors course does not meet the needs of all colleges and universities. One answer to this diversity of opinion regarding the honors course offerings could be the problem involved in selecting an approach to teaching a course that would satisfy a large number of professors. Part B data in Table 25 (Methods for Selecting Students) reinforces this inference by disclosing that there are almost as many ways of selecting students for honors courses as are variety of honors courses. The more popular methods listed were: (1) placement exams, (2) high school science background, (3) high school record, and (4) high school chemistry grade.

There was insufficient evidence to detect a trend with relation to the suitability of "available" textbooks specifically designed for the honors course, however, the majority of the university professors (Part C of Table 25) felt that suitable textbooks and laboratory manuals are available. The reader is directed to Part B of Table 25 for an analysis of some of the practices and suggestions of individual professors.

Objectives and Aims of Introductory College Chemistry

The purpose of Part II of the questionnaire was to obtain the beliefs of chemistry professors concerning the purposes and aims of chemistry instruction for the student planning on specializing in science. A list of 24 possible objectives of first-year college chemistry, was assembled from several sources;[190] a space under the title Other was also provided to encourage individual addition. To determine any difference in opinions of the respondents (the 210 college professors from a total of 212 institutions in the four college categories), the resulting replies were recorded in terms of percentages and under the headings of Very Important, Some Importance, and Not at All Important in Table 26. Included in the possible list of objectives and aims were topics previously mentioned in Chapter II describing new first-year chemistry innovations in individual institutions of higher education.

Two replies were not in proper form for tabulation and, although additional comments were invited, only two professors made such contributions. In one institution the questionnaire was answered by a committee of professors within the chemistry department; six institutions indicated two members in consultation completed the questionnaire while in others the professors as individuals supplied the information.

The percentage approval which constituted sufficient approval to justify the acceptance of a given aim as a general objective was difficult to establish. As a basis for discussion, when 75 per cent of the replies were marked Very Important, the objective was taken as generally accepted. When 67 per cent of the respondents scored the item Very Important, the objective was rated as being accepted by most professors. A percentage of fifty-five to sixty was interpreted as

---

[190] Objectives of first-year college chemistry were taken from articles in The Journal of Chemical Education (listed in the Periodical section of the Bibliography), the publications of the Advisory Council on College Chemistry (listed in the Bulletin section of the Bibliography) and from the objectives listed in the Foreword of many current chemistry textbooks and laboratory manuals.

TABLE 26. OBJECTIVES AND AIMS OF THE INTRODUCTORY COLLEGE CHEMISTRY COURSE

Objectives and Aims	Number of Institutions Responding														
	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	A[a]	S[b]	D[c]	A	S	D	A	S	D	A	S	D	A	S	D
1. Show the relationship of chemistry to other sciences.	41	37	2	34	38	3	27	14	0	9	3	0	111	92	5
2. Help the student to understand the nature of matter and its transformations.	75	5	0	72	4	1	38	3	0	12	0	0	197	12	1
3. Develop the ability to do critical thinking.	72	8	0	73	4	0	40	1	0	12	0	0	197	13	0
4. Make students familiar with the facts, principles, and concepts of chemistry.	71	9	0	71	6	0	38	3	0	8	4	0	188	22	0
5. Acquaint students with new findings of chemistry and to point out their applications to everyday life.	25	53	2	23	52	2	18	22	1	3	8	1	69	135	6
6. Help the student to discover whether he has an aptitude to work in pure or applied science.	26	46	8	26	43	8	16	21	4	3	6	3	71	116	23
7. Give students an idea of the importance and significance of chemistry in our national life.	17	53	10	20	48	9	21	17	3	4	6	2	62	124	24
8. Development of specific interests, habits, and abilities which should be contributed to by <u>all courses</u> in science.	45	32	3	34	31	9	22	8	1	8	4	0	109	85	13

TABLE 26. (Continued)

Objectives and Aims	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	A	S	D	A	S	D	A	S	D	A	S	D	A	S	D
9. Expand the interest of individual students by encouraging hobbies and outside activities which are related to chemistry.	3	41	36	4	38	35	4	30	7	1	5	6	12	114	84
10. Develop the ability to handle quantitative problems (as they are usually treated in chemistry textbooks).	65	14	1	63	14	0	36	4	0	9	3	0	173	35	1
11. Stimulate the desire to read literature pertaining to beginning chemistry and other scientific work.	24	50	6	22	51	4	21	18	1	5	7	0	72	126	11
12. Teach students to be precise in observation and expression.	70	9	1	70	7	0	38	3	0	12	0	0	190	19	1
13. Involve a student in a scientific inquiry which combines theory and experiments in the solution of the problem.	50	30	0	52	22	1	32	9	0	11	1	0	145	62	1
14. Provide practice and reliable recording of data (the acquisition and ordering of data) and training in how to differentiate between relevant and irrelevant data.	53	27	0	55	20	1	35	6	0	11	1	0	154	54	1
15. Formulate, as well as answer, questions.	47	30	3	45	27	4	26	14	1	9	3	0	127	74	8

TABLE 26. (Continued)

Objectives and Aims	Number of Institutions Responding														
	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	A	S	D	A	S	D	A	S	D	A	S	D	A	S	D
16. Develop intellectual honesty rather than foster the search for the "right" answer.	63	16	1	67	8	1	37	3	1	11	1	0	178	28	3
17. Train the student to analyze errors and to learn how to minimize them by making appropriate modifications in experimental procedure.	37	37	5	43	32	1	27	13	1	9	3	0	116	85	7
18. Train the student to recognize the limitations of a given experimental method and learn how such limitations may be overcome.	36	41	3	42	32	3	30	9	1	9	3	0	117	85	7
19. Provide the student direct experiences related to concepts expounded in the classroom.	42	35	3	44	28	3	25	15	1	8	4	0	119	82	7
20. Demonstrate the extension of human sensory perception by appropriate instruments.	18	40	21	11	46	18	17	22	1	6	4	2	52	112	43
21. Develop selected manipulatory skills involved in laboratory techniques.	32	43	5	34	40	3	27	14	0	5	6	1	98	103	9

TABLE 26. (Continued)

Objectives and Aims	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	Number of Institutions Responding														
	A	S	D	A	S	D	A	S	D	A	S	D	A	S	D
22. To bring the student to the point where he can function in a scientific laboratory, or to enable him to understand the reason for the existence of laboratories and the basis of action carried out by those who work there.	33	39	7	34	41	1	25	15	1	8	4	0	100	99	9
23. Obtain (efficiently) reliable data which can be applied to yield an answer to a meaningful question the investigator has proposed about the behavior of nature.	30	40	9	29	43	4	21	19	1	6	6	0	86	108	14
24. Other (Supplied by Respondents)															
a. Destroy the idea that chemistry is alien or magic.	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
b. To read for content and understand it.	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0

[a]A - very important

[b]S - some importance

[c]D - <u>not</u> <u>at</u> <u>all</u> important

meaning only possible acceptance; conversely, a return of less than 33 per cent response to Very Important was taken as a rejection of the objective.

The findings from the literature survey (see Chapter II, p. 23 and the periodical section of the bibliography) allowed the investigator to surmise that there are almost as many sets of objectives as there are chemists interested in first-year college chemistry. In this survey, however, agreement was found on several objectives of first-year college chemistry that may be considered as generally acceptable (the per cent response to Very Important was 75 per cent or greater).

Those objectives selected from the preselected list of 25 objectives and aims of general college chemistry in Table 26 are: (2) help the student to understand the nature of matter and its transformations, (3) develop the ability to do critical thinking, (4) make the students familiar with the facts, principles, and concepts of chemistry, (10) develop the ability to handle quantitative problems, (12) teach students to be precise in observation and expression, and (16) develop intellectual honesty rather than foster the search for the "right" answer.

The investigator requested the respondents to select what they considered to be the five most significant objectives of introductory college chemistry and to rank these five choices in the descending order of most important to least important. Less than 70 per cent (143 out of 212) of the respondents were responsive to this request. To assist in interpreting the data in Tables 28 through 32, the following procedure was designed to evaluate the participating respondents rank of the five choices. Each statement in Tables 28 through 32 was evaluated by

TABLE 27. PERCENT OF INSTITUTIONS SCORING OBJECTIVES AS VERY IMPORTANT

Objective Number (See Table 26)	Percent of Institutions Responding				
	Univ.	Lib. Arts	Junior Colleges	Spec. Inst.	All Inst.
(1)	51	45	66	75	53
(2)	94	94	93	100	94
(3)	90	95	98	100	94
(4)	89	92	93	67	90
(5)	31	30	44	25	33
(6)	32	31	39	25	34
(7)	21	26	51	33	30
(8)	56	44	53	67	53
(9)	4	5	10	8	6
(10)	81	82	88	75	83
(11)	30	29	51	42	34
(12)	88	91	93	100	90
(13)	62	68	78	92	73
(14)	66	72	85	92	74
(15)	59	59	64	75	61
(16)	79	87	90	92	85
(17)	46	56	66	75	56
(18)	45	55	73	75	56
(19)	53	57	61	67	57
(20)	23	14	41	50	25
(21)	40	44	66	42	47
(22)	41	44	61	67	48
(23)	38	38	51	50	41

assigning the following numerical values to the rank and frequency of choice column: column A, five points; column B, four points; column C, three points; column D, two points and column E, one point. The number of points for each topic rank was added to get an actual score. The percentage-of-importance score was calculated by dividing the actual score by the highest possible score.

Example: Statement 1 in Table 28 was ranked first by two professors, second by one professor, third by three professors, fourth by two professors, fifth by three professors; the total number of checks is 11. Thus

11 x 5 = 55 = highest possible score and the actual score is the sum of (2 x 5) + (1 x 4) + (3 x 3) + (2 x 2) + (3 x 1) = 30. Hence the percentage-of-importance score = $\frac{30}{55} \times 100 = 55$ per cent.

The resulting data reveal that chemistry professors are concerned about course objectives and agree on some general course objectives and aims. On the contrary, however, the professors in the different categories disagree in their order of preference.

An examination of the data in Table 28 reveals that the university professors' choice and rank of the five objectives in Table 26 which they considered as the five most significant general objectives (the response to Very Important in Table 27 was 75 per cent or greater) of freshman college chemistry, in the order of most important to least important, are the objectives listed in Table 28 numbered 3, 2, 4, 10, and 16. The liberal arts professors chose objectives 3, 2, 4, 16, and 10 (see Table 29); the junior college professors' selections were objectives 2, 3, 4, 10, and 13 and 16 (tie) in Table 30; the specialized institution professors' choices were objectives 3, 1, 16, 2 and 12 (tie), and 10 in Table 31; and, in summation, the majority of the respondents from all college classifications affirm (see Table 32) the five most significant general objectives of introductory college chemistry in Table 26 to be: (1) develop the ability to do critical thinking (Objective 3), (2) help the student to understand the nature of matter and its transformations (Objective 2), (3) make the students familiar with the facts, principles, and concepts of chemistry (Objective 4), (4) develop the ability to handle quantitative problems (Objective 10) and (5) develop intellectual honesty rather than foster the search for the "right" answer (Objective 16). A comparison of the data in Tables 28, 29, 30, and 31 show that

TABLE 28. THE FIVE MOST SIGNIFICANT OBJECTIVES OF INTRODUCTORY CHEMISTRY AS RANKED BY UNIVERSITIES

Statement Number in Table 26	Rank and Frequency of Choice A 1st	B 2nd	C 3rd	D 4th	E 5th	Total Number of Checks	Possible Score	Actual Score	Percentage-of-Importance Score and Choice
(1)	2	1	3	2	3	11	55	30	55*
(2)	18	8	7	2	5	40	200	152	76 (2)
(3)	22	18	9	8	2	59	295	227	77 (1)
(4)	13	10	6	7	2	38	190	139	73 (3)
(5)	1	0	4	3	2	10	50	25	50*
(6)	1	0	3	2	1	7	35	19	57*
(7)	0	1	1	2	2	6	30	13	43*
(8)	1	5	2	2	4	14	70	39	56*
(9)	0	0	0	0	0	0	0	0	0*
(10)	11	8	9	9	4	41	205	136	66 (4)
(11)	0	0	1	0	1	2	10	4	40*
(12)	1	5	4	13	9	32	160	72	45*
(13)	2	1	3	3	5	14	70	34	49*
(14)	0	1	1	1	2	5	25	11	44*
(15)	2	4	3	2	3	14	70	42	60*
(16)	6	3	9	3	6	27	135	81	60 (5)
(17)	0	0	1	2	1	4	20	8	40*
(18)	0	0	1	6	4	11	55	19	35*
(19)	0	2	2	0	2	6	30	16	53*
(20)	0	0	0	0	0	0	0	0	0*
(21)	0	1	1	2	7	11	55	18	33*
(22)	0	3	0	2	2	7	35	18	52*
(23)	0	0	0	0	3	3	15	3	20*
(24)	0	0	0	0	0	0	0	0	0*

*These percentage-of-importance scores were deleted for selection since the response to Very Important in Table 27 (University column) was less than 75 per cent.

TABLE 29. THE FIVE MOST SIGNIFICANT OBJECTIVES OF INTRODUCTORY CHEMISTRY AS RANKED BY LIBERAL ARTS COLLEGES

Statement Number in Table 26	Rank and Frequency of Choice A 1st	B 2nd	C 3rd	D 4th	E 5th	Total Number of Checks	Possible Score	Actual Score	Percentage-of-Importance Score and Choice
(1)	2	0	0	2	3	7	35	17	49*
(2)	19	9	7	3	4	42	210	162	77 (2)
(3)	20	18	9	2	2	51	255	205	81 (1)
(4)	17	13	13	7	1	51	255	191	75 (3)
(5)	0	0	1	1	0	2	10	3	30*
(6)	0	4	1	2	2	9	45	25	55*
(7)	0	0	1	4	1	6	30	12	40*
(8)	2	1	2	6	2	13	65	34	52*
(9)	0	0	0	0	0	0	0	0	0*
(10)	1	4	8	10	5	28	140	70	50 (5)
(11)	0	1	0	1	0	2	10	6	60*
(12)	1	5	7	7	10	30	150	70	47
(13)	1	2	4	6	5	18	90	42	47*
(14)	0	0	1	1	5	7	35	10	29*
(15)	0	4	1	5	0	10	50	29	58*
(16)	6	5	11	6	7	35	175	102	59 (4)
(17)	0	0	0	3	3	6	30	9	30*
(18)	0	0	2	0	4	6	30	10	33*
(19)	0	2	0	1	6	9	45	16	36*
(20)	0	0	0	0	0	0	0	0	0*
(21)	0	0	1	2	5	8	40	12	30*
(22)	1	0	2	1	3	7	35	16	46*
(23)	0	1	0	0	1	2	10	5	50*
(24)	0	0	0	0	0	0	0	0	0*

*These percentage-of-importance scores were deleted for selection since the response to Very Important in Table 27 (Liberal Arts column) was less than 75 per cent.

TABLE 30. THE FIVE MOST SIGNIFICANT OBJECTIVES OF INTRODUCTORY CHEMISTRY AS RANKED BY JUNIOR COLLEGES

Statement Number in Table 26	Rank and Frequency of Choice A 1st	B 2nd	C 3rd	D 4th	E 5th	Total Number of Checks	Possible Score	Actual Score	Percentage-of-Importance Score and Choice
(1)	2	2	2	1	3	10	50	29	58*
(2)	12	2	2	3	0	19	95	80	84 (1)
(3)	7	10	2	1	1	21	105	84	80 (2)
(4)	7	9	5	1	1	23	115	89	78 (3)
(5)	1	0	1	0	1	3	15	9	60*
(6)	0	0	3	0	3	6	30	12	40*
(7)	1	0	0	1	0	2	10	7	70*
(8)	1	1	0	1	1	4	20	12	60*
(9)	0	0	0	0	0	0	0	0	0*
(10)	11	5	3	3	2	24	120	92	77 (4)
(11)	1	0	1	1	1	4	20	11	55*
(12)	2	1	3	4	4	14	70	35	50
(13)	1	0	5	5	0	11	55	30	55 (5)
(14)	1	1	0	0	0	2	10	9	90#
(15)	2	1	1	2	2	8	40	23	58*
(16)	4	1	3	5	4	17	85	47	55 (5)
(17)	1	0	0	2	1	4	20	10	50*
(18)	0	0	0	0	1	1	5	1	20*
(19)	0	0	2	2	2	6	30	12	40*
(20)	0	0	0	0	1	1	5	1	20*
(21)	0	0	0	1	2	3	15	4	26*
(22)	1	1	0	0	0	2	10	9	90*
(23)	0	0	0	0	1	1	5	1	20*
(24)	0	0	0	0	0	0	0	0	0*

*These percentage-of-importance scores were deleted for selection since the response to Very Important in Table 27 (Junior College column) was less than 75 per cent.

#Per cent response is low, therefore, this item is deleted for selection.

TABLE 31. THE FIVE MOST SIGNIFICANT OBJECTIVES OF INTRODUCTORY CHEMISTRY AS RANKED BY SPECIALIZED INSTITUTIONS

Statement Number in Table 26	Rank and Frequency of Choice A 1st	B 2nd	C 3rd	D 4th	E 5th	Total Number of Checks	Possible Score	Actual Score	Percentage-of-Importance Score and Choice
(1)	2	0	0	1	0	3	15	12	80 (2)
(2)	1	0	4	1	0	6	30	19	63 (4)
(3)	8	0	0	1	0	9	45	42	93 (1)
(4)	1	2	0	0	2	5	25	11	44*
(5)	0	0	0	0	0	0	0	0	0*
(6)	0	0	0	0	0	0	0	0	0*
(7)	0	0	0	0	0	0	0	0	0*
(8)	0	1	0	0	1	2	10	5	50*
(9)	0	0	0	0	0	0	0	0	0*
(10)	0	1	0	1	0	2	10	6	60 (5)
(11)	0	0	2	0	0	2	10	6	60*
(12)	0	3	1	2	0	6	30	19	63 (4)
(13)	0	0	0	1	1	2	10	3	30
(14)	0	0	0	0	2	2	10	2	20
(15)	0	0	1	0	0	1	5	3	60
(16)	0	2	2	1	0	5	25	16	64 (3)
(17)	0	1	0	1	0	2	10	6	60
(18)	0	0	0	0	2	2	10	2	20
(19)	0	0	0	0	1	1	5	1	20*
(20)	0	0	0	1	1	2	10	3	30*
(21)	0	0	0	0	0	0	0	0	0*
(22)	0	0	0	0	0	0	0	0	0*
(23)	0	0	0	0	0	0	0	0	0*
(24)	0	0	0	0	0	0	0	0	0*

*These percentage-of-importance scores were deleted for selection since the response to Very Important in Table 27 (Specialized Institution column) was less than 75 per cent.

TABLE 32. THE FIVE MOST SIGNIFICANT OBJECTIVES OF INTRODUCTORY CHEMISTRY AS RANKED BY ALL INSTITUTIONS

Statement Number in Table 26	Rank and Frequency of Choice A 1st	B 2nd	C 3rd	D 4th	E 5th	Total Number of Checks	Possible Score	Actual Score	Percentage-of-Importance Score and Choice
(1)	8	3	5	6	9	31	155	88	57*
(2)	50	19	20	9	9	107	535	413	77 (2)
(3)	57	46	20	12	5	140	700	558	80 (1)
(4)	38	34	24	15	6	117	585	434	74 (3)
(5)	2	0	6	4	3	15	75	39	52*
(6)	1	4	7	4	6	22	110	56	51*
(7)	1	1	2	7	3	14	70	32	46*
(8)	4	8	4	9	8	33	165	90	55*
(9)	0	0	0	0	0	0	0	0	0*
(10)	23	18	20	23	11	95	475	304	64 (4)
(11)	1	1	4	2	2	10	50	27	54*
(12)	4	14	15	26	23	82	410	196	48
(13)	4	3	12	15	11	45	225	109	49*
(14)	1	2	2	2	9	16	80	32	40*
(15)	4	9	6	9	5	33	165	97	59*
(16)	16	11	25	15	17	84	420	246	59 (5)
(17)	1	1	1	8	5	16	80	33	41*
(18)	0	0	3	6	11	20	100	32	32*
(19)	0	4	4	3	11	22	110	45	41*
(20)	0	0	0	1	2	3	15	4	27*
(21)	0	1	2	5	14	22	110	34	31*
(22)	2	4	2	3	5	16	80	43	54*
(23)	0	1	0	0	5	6	30	9	30*
(24)	0	0	0	0	0	0	0	0	0*

*These percentage-of-importance scores were deleted for selection since the response to Very Important in Table 27 (All Institutions column) was less than 75 per cent.

college professors, regardless of the classification of institution, in general, agree on the five general objectives of freshman chemistry but disagree in their order of preference. Respondents to the questionnaire were most in agreement that item 3 in Table 32 (develop the ability to do critical thinking) is the most important aim for the introductory course for students who are specializing in chemistry or some other science. The comments on objective 4 in Table 28 (the course should make students familiar with the facts, principles, and concepts of chemistry) suggest that students enrolled in a first-year college chemistry course designed for science majors should be familiar, but not expert, in the use of these facts, principles, and concepts; and that only sufficient material should be introduced to unify and develop these principles.

Other aims listed in Table 26 were generally regarded as being of some importance and the ensuing description suggests those aims and objectives to be related to the designing of laboratory experiments, the practice and reliable use of data, and the development of laboratory technique.

The objectives in Table 26 accepted by most professors (response to Very Important in Table 27 was at least 67 per cent but less than 75 per cent) are: (1) involve students in a scientific inquiry which combines theory and experiments in the solution of a problem (Objective 13), (2) provide practice and reliable reporting of data and training in how to differentiate between relevant and irrelevant data (Objective 14).

The objectives in Table 26 receiving a possible acceptance rating (a percentage return of 55 to 60 per cent) were: (1) development of special interest, habits, and abilities which should be contributed to by all courses of science (Objective 8), (2) formulate, as well as answer questions (Objective 15), (3) train the students to analyze errors and to learn how to minimize them by making appropriate modifications in experimental procedures (Objective 17), (4) train the student to recognize the limitations of a given experimental method and learn how such limitations may be overcome (Objective 18), (5) provide the student direct experiences related to concepts expounded in the classroom (Objective 19), (6) develop selected manipulatory skills involved in laboratory techniques (Objective 21), (7) bring the student to the point where he can function in a scientific laboratory (Objective 22).

The professors from all institutions surveyed (see Table 26) rejected (response to Very Important in Table 27 was less than 33 per cent) the following objectives: (1) acquaint students with new findings of chemistry and to point out their application to everyday life (Objective 5), (2) give students an idea of the importance and significance of chemistry in our national life (Objective 7), (3) expand the interest of individual students by encouraging hobbies (Objective 9), and (4) demonstrate the extension of human sensory perception by appropriate instruments (Objective 20). Two respondents added objectives to the initial list of possible objectives and aims which they felt should be worthy of mention. These are: (1) destroy the idea that chemistry is alien or magic, and (2) to read for content and understand it.

Course Evaluation

An excessive amount of staff time can be consumed in determining the worth of a first-year college chemistry course. The selection of standards for evaluating a first-year college chemistry course is difficult whether that evaluation be short or long range.

This combination of findings (i.e., the literature findings in Chapter II, the survey data in Chapters IV and V, the articles in the bibliography related to new innovations at the introductory college chemistry level) reveal that introductory college chemistry professors face an increasing number of curricular decisions. Each year a professor must decide whether or not to abandon his introductory chemistry textbook or course with which he is usually very familiar in favor of one or more of the many new textbooks or innovations.

The investigator believes that a professor must examine the relative merits of the many options according to criteria for his own college situation. Decisions confront introductory college chemistry professors and information to make these decisions is the responsibility of course (or curriculum) evaluation. Evaluation is gathering information for the purpose of making decisions.[191] The information may take the form of objective description and/or personal judgment. Course evaluation is synonymous to educational research; it differs from research in its orientation to a specific course rather than the variables common to many courses. Although teacher guides, film, textbooks, and journal publications have been useful, what appears to be lacking is research evidence concerned with teacher decision.

Methods of Determining Worth of the Introductory Course

The purpose of Part II, Section 26 of the Questionnaire was to

---

[191]Wayne W. Welch, "Curricular Decisions-How Can Evaluation Assist Science Teachers?" The Science Teacher, 35, (November, 1968), p. 23.

TABLE 33. METHODS OF DETERMINING THE WORTH OF THE INTRODUCTORY CHEMISTRY COURSE

Methods of Evaluation	Number of Institutions Responding														
	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	S[a]	P[b]	T[c]	S	P	T	S	P	T	S	P	T	S	P	T
1. Special examination.[d]	2	18	20	1	30	31	0	25	25	3	5	8	6	78	84
2. Subjective observations.	29	11	40	20	6	26	15	2	17	4	3	7	68	22	90
3. By using a student-completed questionnaire.	2	20	22	1	13	14	4	6	10	1	1	2	8	40	48
4. Discussion involving the entire chemistry faculty.	31	14	45	21	12	33	6	3	9	2	0	2	60	29	89
5. No evaluation.	0	0	7	0	0	8	0	0	2	0	0	2	0	0	19
6. Other (supplied by respondents)															
a. Follow-up in subsequent courses.	0	0	0	0	0	0	2	2	4	0	0	0	2	2	4
b. Daily quiz.	0	0	0	0	1	1	1	0	1	0	0	0	1	1	2
c. ACS General Chemistry Examination.	0	4	4	0	7	7	0	3	3	0	0	0	0	14	14
d. Student or student committee evaluation.	1	4	5	0	1	1	0	0	0	0	0	0	1	5	6
e. Graduate Record Exam.	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
f. Success of students (GRE) in graduate work.	3	0	3	2	1	3	0	0	0	0	0	0	5	1	6
g. Number and quality of students majoring in chemistry.	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
h. Lab reports.	0	0	0	0	3	3	0	0	0	0	0	0	0	3	3
i. Test on qualitative unknowns.	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
j. Homework evaluated.	0	0	0	0	2	2	0	0	0	0	0	0	0	2	2
k. Subjective observations and student questionnaires.	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1

TABLE 33. (Continued)

Methods of Evaluation	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	S	P	T	S	P	T	S	P	T	S	P	T	S	P	T
6. Other (supplied by respondents) (continued)															
l. Departmental exams are given and periodically questionnaires are given to students.	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
m. Discussion among faculty teaching the course.	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
n. Course is evaluated very critically by the undergraduates in their annual independent publication, "Confidential Guide to Courses Regularly Open to Freshmen".	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
o. Combination of 2, 3, and 4.	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1
p. First 4 choices and performance in advanced courses.	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1
q. Informal discussions with students.	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1
Totals	68	77	152[e]	45	77	130[e]	28	44	74[e]	10	7	21[e]	151	203	373[e]

[a]S - spasmodic

[b]P - periodic

[c]T - Total

[d]A short examination composed of four or five questions seeking student criticism with respect to course methodology, course objectives, and teaching procedure.

[e]The respondent checked one or more of the listed methods of evaluation but failed to indicate whether the method was spasmodic or periodic.

determine the methods currently being used to evaluate the introductory college chemistry course. The tabulations concerning the ensuing methods used to evaluate general college chemistry courses include, in addition to the preselected list in Table 33, a space under the choice Other to encourage additional suggestions.

That 84 of the respondents marked item 1 (special examination) could possibly indicate that some of the professors confuse course success with student success. The observation that no respondent revealed the nature of the special examination tends to support this previous statement. The more popular methods used to evaluate the success of the first-year college chemistry course (see Table 33) are subjective observations (Method 2), and discussion involving the entire chemistry faculty (Method 4). The evaluation methods, in general, were indicated to be spasmodic rather than periodic. The use of student completed questionnaires was indicated by 48 of the 212 respondents (Method 3).

Individual professors attached comments which revealed some additional ideas relative to methods of course evaluation. Those ranged from yearly evaluations to the follow-up and success of students in subsequent upper level chemistry courses, including graduate work. The findings revealed (Method 5) only 19 colleges and universities (a 9 per cent response) indicated no attempt at course evaluation.

Examination of the findings in Table 33 reveals chemistry professors have designed several varieties of methods to evaluate the introductory college chemistry course. The 42 per cent response (90 out of 212) to Method 2 (subjective observations) also suggests a lack of standard methods for course evaluation. The need for a satisfactory objective method of evaluating the introductory college chemistry course was also suggested by the fact that the most popular methods used for course evaluation were subjective observations (item 2) and discussion involving the entire chemistry faculty (item 4).

The responding professors attached several course evaluation suggestions to the questionnaire returns which could possibly provide assistance in making teacher decisions with respect to course evaluation: Follow-up in subsequent courses (6-a), American Chemical Society General Chemistry Examination (6-c), student or student committee evaluation (6-d), success of students (Graduate Records Examination) in graduate work (6-f), number and quality of students majoring in chemistry (6-g), subjective observations and students questionnaires (6-k), critical evaluation by the undergraduates in their independent publication (6-n), and informal discussions with students (6-q). The low percentage use of those methods of course evaluation, however, suggest the need for research in course evaluation which is necessary for the continued improvement of professor effectiveness in introductory college chemistry.

Summary

Referring to item 2, Table 16, suggests that the majority of introductory college chemistry professors do not feel that the introductory college course in chemistry is, in general, satisfactory for the chemistry major. The responses of professors in this survey seem to indicate that a general uncertainty exists concerning what chemistry instruction should do for the science major. The large proportion of the instructors regard the development of critical thinking, familiarity with the facts and principles of chemistry, and development of the ability to handle quantitative problems as three of the five most important outcomes for the science major, yet the survey findings indicated rather clearly that there seems to be no objective method to determine whether an introductory course was successful. This paradox raises the following questions: "What is meant by critical thinking in chemistry?", "What are some of the criteria which would enable a chemistry professor to select and justify the inclusion of certain concepts and chemistry principles in an introductory chemistry course?" Answers to those questions may yield the information necessary for the formulation of a satisfactory objective method of evaluating the introductory college chemistry course.

CHAPTER VI

SUPPLEMENTARY TEACHING MATERIALS, EQUIPMENT, AND TEACHING METHODOLOGY AND TEACHING TECHNIQUES

A compendium of supplementary teaching materials and teaching methodologies used by the professors of introductory college chemistry participating in the study is presented in this chapter. Supplementary teaching materials and teaching methods are only incidentally mentioned in the literature; the topics listed in Tables 34 through 37 are based on the data obtained from the response to Part III of the Questionnaire and were prepared from the literature findings.

Pedagogical Practices With Respect to Teaching Methodology and Teaching Techniques, and Teaching Materials

The purpose of Part III of the Questionnaire was to obtain the practices of chemistry professors concerning supplementary teaching materials, teaching methodology and teaching techniques used with the student majoring in science. These topics contain 56 items including 16 items in three separate categories entitled "Other" (see Tables 34 and 35). The data in these two tables and literature findings, including the recommendations of the Advisory Council on College Chemistry,[192] agree on the audio-visual materials and/or equipment which a college chemistry professor should have

---

[192]Haenisch, "Modern Teaching Aids for College Chemistry," pp. 1-2.

TABLE 34. NUMBER AND PERCENT OF INSTITUTIONS CHECKING SUPPLEMENTARY MATERIALS USED FOR INTRODUCTORY COLLEGE CHEMISTRY COURSES IN-CLASS BY INSTRUCTORS AND OUTSIDE-THE-CLASSROOM BY STUDENTS

Topic	Number of Institutions Responding											
	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Institutions			
	C[a]	O[b]	C	O	C	O	C	O	C	%	O	%
1. Faculty prepared study guides	8	22	19	26	12	15	3	5	42	20	68	32
2. Student personal data inventories	10	2	11	0	10	0	2	0	33	16	2	1
3. File of previously given tests	8	28	14	19	15	4	2	0	39	18	51	24
4. Bibliography of reading materials	1	20	3	30	5	15	1	1	10	5	66	31
5. Articles	11	18	15	21	16	21	2	1	44	21	61	29
6. Books	12	31	10	42	17	31	2	4	41	19	106	50
7. Film loops	7	4	12	4	17	7	1	0	37	17	15	7
8. Programmed materials	3	27	8	27	4	18	1	1	16	8	73	34
9. Other (supplied by respondents)	3	3	1	2	1	0	0	0	5	2	5	2
(a) Study guide prepared by publisher	1	1	0	0	0	0	0	0	1	0	1	0
(b) Charts	1	1	0	0	0	0	0	0	1	0	1	0
(c) Workbook	1	1	0	0	0	0	0	0	1	0	1	0
(d) Single concept films	0	0	0	0	1	0	0	0	1	0	0	0
(e) Chemistry library	0	0	0	1	0	0	0	0	0	0	1	0
(f) Tape recordings	0	0	1	1	0	0	0	0	1	0	1	0

TABLE 34. (Continued)

Topic	Number of Institutions Responding											
	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Institutions			
	C	O	C	O	C	O	C	O	C	%	O	%
10. Atomic and molecular models	65	15	67	19	36	13	10	4	178	84	51	24
11. Film strips	14	0	26	1	22	1	5	0	67	32	2	1
12. Overhead projector	44	1	47	0	29	1	6	0	126	59	2	1
13. Opaque projector	13	1	14	0	10	1	3	0	40	19	2	1
14. 8 mm or 16 mm projector	30	1	33	1	23	1	4	0	90	42	3	1
15. Closed circuit TV	1	0	2	0	1	0	1	1	5	2	1	0
16. Other (supplied by respondents)												
(a) Transparencies, slides	4	0	0	0	0	0	0	0	4	2	0	0
(b) 2" x 2" slide projector	1	0	0	0	0	0	0	0	1	0	0	0
(c) Demonstration spectroscope	1	0	0	0	0	0	0	0	1	0	0	0
(d) Demonstration magnetic susceptibility apparatus	1	0	0	0	0	0	0	0	1	0	0	0
17. Paperback books	15	61	15	59	10	22	4	10	44	21	152	72
18. Videotape	2	2	1	1	3	1	1	0	7	3	4	2
19. Computer assisted instruction	3	5	1	3	0	0	0	0	4	2	8	3

TABLE 34. (Continued)

Topic	Number of Institutions Responding											
	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Institutions			
	C	O	C	O	C	O	C	O	C	%	O	%
20. Supplementary paperback materials bought by students as part of supplies	0	0	1	1	0	0	0	0	1	0	1	0
21. Special lab and problem sets	1	1	0	0	0	0	0	0	1	0	1	0
22. Colored chalk	1	0	0	0	0	0	0	0	1	0	0	0

[a]C - Classroom

[b]O - Outside the classroom

at his disposal. Those audio-visual materials are television tapes (video tape), a library of film loops on laboratory techniques, film loop projector, 8 mm and 16 mm films, overhead projector and transparency sets, programmed materials (commercial and/or staff prepared), and computer assisted instruction (CAI).[193] In addition, AC_3 also requested that an effort be made to stimulate the preparation of a series of outlines, paperbacks, and recommendations with respect to teaching methodology essential to the improvement of the teaching of introductory college chemistry. The survey findings reveal an 84 per cent in-class use and a 24 per cent out-of-class use of atomic and molecular models (item 10 in Table 34).

A number of comments by the respondents were attached either to the questionnaire or to course outlines or syllabi enclosed with the returned completed questionnaires. Those comments included reporting on the use of recitation sessions, problem solving sessions, and student presentation and solutions to problems to be of educational value to the teaching of first-year college chemistry. Self instruction, on part of the student, was also suggested as a learning aid and the respondents reported that this assistance can come from programmed instruction, videotapes, film loops, and computer assisted instruction. Six professors also reported the use of programmed lessons as ways to handle some topics which students may not have mastered; class time would then be free for topics that are new to all students.

A Summary of the Use of Supplementary Teaching Materials, Teaching Methodology and Teaching Techniques

The 20 per cent in-class use and 32 per cent out-of-class use of

---

[193]Ibid., p. 21.

faculty prepared study guides (Table 34, All Institutions column, item 1) reveal that some institutions deem it necessary to provide students with some educational experiences in how to study chemistry; one respondent indicated the use of a commercial study guide. The data in Table 34 reveal an in-class use of study guides to range from a low of 9.8 per cent in the university category to a high of 29.3 per cent in the junior college classification; the in-class use in the liberal arts and specialized institutions categories is 24.7 and 25.0 per cent, respectively. A similar trend is revealed with respect to the outside-the-classroom use of study guides; the data in Table 34 show a low of 26.8 per cent use in the university category and a high of 46 per cent in the specialized institution classification with a per cent usage of 33.8 and 36.6 in the liberal arts and junior college categories. A comparison of the in-class and out-of-class use of study guides infers that the respondents favor the outside-the-classroom use and suggests that the responsibility of the use of a study guide is left largely to the prerogative and discretion of the student. That the university category was low in both study guide categories and the junior college was high in both also suggest more professional assistance to students with respect to study habits in the junior college category.

The investigator and colleagues have found that a file of old examinations make good study guides and, in addition, acquaint students with the type of test and the nature and type of questions to be expected on a scheduled examination. The 18 per cent in-class use and 24 per cent outside-the-classroom use of a file-of-previously-given examinations (Table 34, item 3, All Institutions column) indicates that some of the

TABLE 35. METHODOLOGY AND TEACHING TECHNIQUES USED IN INTRODUCTORY COLLEGE CHEMISTRY

Methods and Techniques Used	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
1. Demonstrations.	64	78	58	75	35	85	10	83	167	78
2. Panel Discussions.	3	3	2	2	1	2	0	0	6	2
3. Team teaching and/or committee teaching.	15	18	9	11	3	7	3	23	30	14
4. Programmed instruction.	18	21	23	29	9	21	1	8	51	24
5. Review sessions and/or tutorial sessions.	66	80	65	84	31	75	9	75	171	80
6. Conference quizzes.	23	28	13	16	7	17	0	0	43	20
7. Series of quizzes, tests.	57	69	65	84	37	90	10	83	168	79
8. Student conferences with faculty members.	44	53	53	68	31	75	9	75	137	64
9. Regular problem assignments.	67	81	67	85	40	97	10	83	183	86
10. Urge use of library for other than textbook reading.	36	43	46	59	29	70	8	66	119	56
11. Require term papers on topics not adequately covered in textbooks or secondary resources.	4	4	7	9	6	14	1	8	18	8
12. Special topics and reports.	6	7	11	14	9	21	1	8	27	12
13. Student presentation of problems and solutions.	10	12	18	23	9	21	3	25	40	18
14. Assign research journal articles for reading.	5	6	8	10	4	9	0	0	17	8
15. Presenting the limited but useful aspects of "black box" instruments.	15	18	5	6	3	7	2	16	25	11
16. Let student plan, execute, and interpret experiments.	9	10	11	14	6	14	3	25	29	13

TABLE 35. (Continued)

Methods and Techniques Used	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
17. Using "open-ended" experiments.	16	17	20	26	9	21	4	33	49	23
18. Devise experiments so that original sources must be consulted.	7	8	5	6	7	17	1	8	20	9
19. Using laboratory experiments which are not dependent on materials discussed in the classroom.	32	39	31	40	23	56	7	58	93	43
20. Using simple "mock-up" rather than complex apparatus to concentrate the student's attention on ideas rather than manipulation.	12	14	16	20	11	26	1	8	40	18
21. Other (Supplied by Respondents)										
(a) Study topic in form of a symposium.	0	0	1	1	0	0	0	0	1	1
(b) Formal lectures and scheduled exams--3 exams per semester.	1	1	1	1	0	0	0	0	2	1
(c) Lots of give and take in class rather than formal, uninterrupted lecture.	0	0	1	1	0	0	0	0	1	1
(d) Use "teacher planned experiments" that students must perform and interpret accurately.	0	0	1	1	0	0	0	0	1	1
(e) Lectures modified by frequent oral quizzing and discussion.	0	0	1	1	0	0	0	0	1	1
(f) Laboratory experiment conducted in class.	1	1	0	0	0	0	0	0	1	1

responding professors have also found copies of previously given examinations to be an educational asset. The low per cent response to items 7 (film loops), 9-d (single concept films), 9-f (tape recordings), 11 (film strips), 12 (overhead projector), 14 (8 mm and 16 mm projector), 15 (closed circuit television), 18 (video tape) and 19 (computer assisted instruction) in Table 34 and item 15 (black-box experiments) in Table 35, indicates that first-year college chemistry professors are not utilizing the teaching aids as recommended by the Advisory Council on College Chemistry.[194] The 84 per cent in-class use and a 24 per cent outside-the-classroom use of atomic and molecular models (topic 10 in Table 34, All Institutions column), however, suggest that professors are making full use of these educational aids. The professors report, in Table 34, a 42 per cent and a 59 per cent in-class use of the 8 mm and/or 16 mm projector (item 14), and the overhead projector (item 12). The 17 per cent in-class use of the 8 mm film loops (item 7) suggests that the 16 mm projector is, at present, the most important; although single concept films are now readily available, only one respondent indicated use. A 3 per cent use of computer assisted instruction (CAI) largely as an outside-the-classroom aid by universities, liberal arts colleges, and specialized institutions was indicated; CAI has been approved and encouraged by the Advisory Council on College Chemistry.

The 78 per cent response to item 1 in Table 35, All Institutions column, reveals that the introductory college chemistry professor's most popular teaching technique other than lecture, is <u>demonstration</u>. The response to the questionnaire (see Tables 34 and 35) seems to indicate

[194]Ibid.

that little use is made of the student's time outside-the-classroom and laboratory for self-instruction.

Increasing use of the library is suggested by the fact that 31 per cent (Table 34, item 4) of the instructors report that their departments have prepared bibliographies of reading materials related to the interest of those non-traditional topics which may not be covered in the regular course sequence. Additional use of the library is indicated by the fact that 56 per cent of the professors report that they urge students to use the library for other than textbook reading (Table 35, item 10) and 8 per cent assign research journal articles for reading (Table 35, item 14). The educational value of those library assignments is not easily determined since only 12 per cent of the respondents report the assignment of special topics and reports (Table 35, item 12) and only 8 per cent (Table 35, item 11) require term papers on topics not adequately covered in textbooks or secondary reference resources. That 72 per cent of all respondents (Table 34, item 17) report an outside-the-classroom use of paperbacks further complicates the elucidation of the true nature of library assignments. The following findings also suggest alternate uses of the library.

1. Thirteen per cent of the professors allow students to plan, execute, and interpret experiments (Table 35, item 16).

2. Twenty-three per cent of the respondents report the use of open-ended experiments (Table 35, item 17) and 9 per cent devise experiments so that students must consult original sources (Table 35, item 18).

3. Forty-three per cent of the professors report the use of laboratory experiments which are not dependent on materials discussed in the

lecture portion of the introductory chemistry course (Table 35, item 19).

The findings in Chapter V suggest that introductory college chemistry professors are often reluctant to reorganize a course until a suitable textbook is available. Using a textbook that does not fit the course, using several textbooks, or no textbook at all can have several advantages.[195] For example, with no basic textbook to rely upon both professors and students are forced to approach the content in an independent fashion; they must think analytically about what they read and less dependent on "what the book says." Thus, analytical attitude about reading must exist because there is no upper limit set upon what must be learned as a class-adopted textbook can do. The distance from the use of multiple secondary library sources to the use of original literature is only a small step. The use of chemical literature can be fostered by assigning readings from journal articles, designing experiments which require the use of the original literature, and requiring term papers on topics not adequately covered in textbooks or secondary sources. Another reason for encouraging and even demanding that students become acquainted with the chemical literature is the tremendous bulk of published information. No curriculum can deal with more than a minute fraction of the available descriptive chemistry. Students must see something of the scope of factual information available and the best place for them to see it is in the library.[196] The data in Table 35 show a slight trend toward the utilization of the above-mentioned uses for library assignments in both the lecture and laboratory portions of the freshman college chemistry course. That only

---

[195]Hume, "Experimental Curricula," p. 31.

[196]Ibid.

approximately one-half of those professors who assigned library readings also prepare a bibliography, however, raises questions. What kind of experiences are first-year college chemistry students receiving with respect to the proper retrieval of chemistry information from either the college and/or chemistry department library? What is the nature of the library reading assignments?

The teaching method, second to lecture, shown by an 86 per cent usage, is the daily or weekly assignment of problems (Method 9, All Institutions column, Table 35). Other favored teaching methods listed in Table 35, in descending order of preference, are: series of quizzes and tests (Method 7) and demonstrations (Method 1); the professors reported a 79 and 78 per cent use of these methods. An 80 per cent use of review sessions and/or tutorial sessions (Method 5) was also reported; no one will question the educational value of this reservation of time by professors to provide assistance to students. That teaching methodologies are being used which are inextricably related to the problem of formulating a point of view concerning the provision of assistance to needed students were revealed by the findings in the previous statements and are further supported by additional findings which reveal that 53 per cent of the universities, 68 per cent of the liberal arts colleges, and 75 per cent of the junior colleges and specialized institutions (a 64 per cent response by all professors to item 8 in Table 35) schedule student conferences with faculty members.

The above findings imply that professors believe learning experiences are more effective through lectures and demonstrations, rather than through individual discussion and participation; however, professors are showing a willingness to render assistance to needy students (Table 35). That only 14 per cent of all respondents favor the use of teaching and/or committee teaching also suggest that each professor teaches the general chemistry course according to his individual preference.

The fact that 86 per cent of the professors in all institutions report the use of regular problem assignments, yet only 18 per cent indicate student involvement in the presentation of problems and their solution, represent opposite points of view concerning whether or not to involve students in the solution of problems. That only one institution out of five assigning problems allows the student to express himself by presenting problems and their solutions to the class raises questions as to the nature of review and/or tutorial sessions.

Possibly the low per cent usage of black boxes (11 per cent response to Method 15 in Table 35) in the first course in college chemistry can be attributed to the fact that black boxes are necessary only for illustrating certain basic principles, motivating the student, and perhaps in research. Most of these things can be accomplished by alternate methods.

According to Young[197] and the finding in this survey,[198] the primary objective of the laboratory is to develop critical thinking; the low per cent response to the use of open-ended experiments (23 per cent response to item 17 in the All Institutions column, Table 35)[199] infers

---

[197]See p. 22 in this dissertation.

[198]See Tables 28-31.

[199]The open-ended experiment allows a student to perform an experiment at his own pace (within limits), and the student is encouraged to find answers at the time they arise during the course of the laboratory work.

that the laboratory is probably not being used to achieve its objective. The 43 per cent positive response to Method 19 (using laboratory experiments which are not dependent on materials discussed in the classroom) in Table 35 reveals, however, that experiments are currently being used which are not dependent on materials discussed in class. This implies that some laboratory experiments are being used to supplement and reinforce the lecture; the Advisory Council on College Chemistry approves the use of laboratory experiments which are not dependent on materials discussed in lecture.

Individual panel members of the Advisory Council have suggested that library study be an integral part of laboratory work; the survey finding reveal a 56 per cent response to item 10 (urge use of library for other than textbook reading) and an eight per cent response to item 14 (assign research journal articles for reading) and suggest that some of the respondents are following the recommendations.

Equipment and Outside Materials

The Advisory Council on College Chemistry recommended that every chemistry department should have as part of its laboratory and demonstration equipment, in addition to a lecture table, a digital voltmeter or equivalent, pH meters, several automatic (single pan) balances, and spectrophotometric apparatus.[200] The pH meter and spectrophotometer provide means by which quantitative information can be gained in areas such as kinetics, metal ion determination, buffer systems and weak acid-base titrations. Direct reading balances are valuable time savers and a necessary part of statistical work in the study of laboratory accuracy and

---

[200]Haenisch, "Modern Teaching Aids in College Chemistry," p. 2.

precision and can be of real teaching value by permitting a wider latitude of experiments.

The decision to use the nine pre-selected items of apparatus in Table 36 was dictated by the suggestions of the Advisory Council on College Chemistry through their various publications and the members of the questionnaire evaluation committee. The data in Table 36, item 1, reveal a high percentage use of direct reading balances. The principal use of these balances is for student experiments but they are also used in demonstrations and study of design.[201] Direct reading balances were reported to be used in student experiments by 73 of 82 universities, 46 of 77 liberal arts colleges, 31 of 41 junior colleges, and 7 of 12 specialized institutions. The use of pH meters in student experiments was reported by 55 per cent of all respondents (Equipment item 5, Table 36); also a 25 per cent use in demonstration was reported. The use of the spectrophotometer (Equipment item 4) in student experiments was reported by 38 per cent of all respondents. The professors indicated the common usage of 30 other additional items of equipment in addition to that apparatus ordinarily assigned to students in general chemistry laboratories. The geiger counter or scintillator (Table 36, item 8) received a 25 per cent usage while paperchromatography usage was 22 per cent. The low per cent usage of equipment, other than the direct reading balance, the spectrophotometer, and the pH meter, raises several questions as to the nature of the first-year college chemistry experiments.

---

[201]The use of low-cost simple instruments designed in a manner to permit a student to learn more chemistry information such as Infra Red spectra from an instrument whose workings can be actually observed and which may break down and be repaired.

TABLE 36. EQUIPMENT USED IN INTRODUCTORY COLLEGE CHEMISTRY

Equipment Used	Number of Institutions Responding																	
	Universities			Liberal Arts			Jr. Colleges			Specialized			All Institutions					
	D[a]	SE[b]	SD[c]	D	SE	SD	D	SE	SD	D	SE	SD	D	%	SE	%	SD	%
1. Direct reading balances	8	73	2	17	46	6	8	31	2	5	7	0	38	18	157	74	10	5
2. Gas chromatograph	5	3	0	11	4	0	7	10	5	1	1	0	24	11	18	8	5	2
3. Infra-red spectrophotometer	6	6	1	13	5	1	3	5	2	1	1	0	23	11	17	8	4	2
4. Bausch and Lomb Spectronic 20	5	34	0	5	23	3	6	20	3	1	4	1	17	8	81	38	7	3
5. pH Meter	13	53	0	21	32	3	14	27	2	4	5	1	52	25	117	55	6	3
6. Conductivity bridge	5	14	0	9	5	0	2	3	2	1	2	0	17	8	24	11	2	1
7. Polarimeter	3	4	0	8	4	0	4	2	2	0	1	0	15	7	11	8	2	1
8. Geiger counter or scintillator	20	19	0	29	19	2	12	12	3	2	2	0	63	30	52	25	5	2
9. Paperchromatography	6	15	0	7	19	0	3	11	3	2	2	0	18	8	47	22	3	1
10. Other (Supplied by Respondents)																		
a. Thin layer chromatography	0	2	0	0	1	0	0	3	0	0	0	0	0	0	6	3	0	0
b. Double pan analytical balances	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
c. Column chromatography	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
d. Photometer-flame, electrolytic analysis	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
e. Colorimeter	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
f. Nuclear magnetic resonance	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
g. Vacuum tube voltmeter	0	1	0	0	3	0	0	0	0	0	0	0	0	0	4	2	0	0
h. Vacuum line-potentiometer	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
i. Welch chem. anal. system	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
j. Buoy balance	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
k. Beckman DU electrophoresis	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
l. Ion exchange	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
m. Electrodeposition	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
n. Centrifuge	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
o. Chain-o-matic balances	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
p. Refractometer	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
q. Spectro-electro titrator	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0

[a]D - Demonstration

[b]SE - Student Experiments

[c]SD - Study of Design

TABLE 37. OUTSIDE MATERIALS USED IN INTRODUCTORY COLLEGE CHEMISTRY

Materials Used	Number of Institutions Responding					
	Universities	Liberal Arts	Junior Colleges	Specialized	All Institutions	Percent
1. Field trips	9	17	11	1	38	18
2. Exploration trips	3	13	2	0	18	8
3. Local industry	6	19	8	0	33	16
4. Resource speakers	20	36	13	3	72	34
5. Chemistry club and parties	50	42	7	4	103	49
6. Other (Supplied by Respondents)						
a. ACS affiliate	0	3	1	2	5	2
b. Educational Activity Period for research and demonstration	0	1	0	0	1	0
c. Occasional speakers to science club	0	1	0	0	1	0

That only 72 (34 per cent) of all institutions in the sample returns utilize outside speakers (item 4 in All Institutions column, Table 37) raises the question about the educational value of this existing resource at the freshman level. That 50 per cent of university professors and 42 per cent of the liberal arts professors extend an invitation for eligible students to engage in chemistry club activities and social parties suggest that some of the institutions are designing methods to improve and strengthen interest in chemistry and to show personal interest in students and hopefully, the converse.

The investigator's feeling is that colleges and universities need to show interest in students and give them more than a two by four educational experience--inside the two book covers and the four walls. Resource speakers, clubs and social activities, open-ended investigations, and industrial trips represent some of the procedures that can be used.

Comparison of Methodology and Teaching Techniques between Institutions

A tabulation of t-scores to determine whether a significant difference exists between the means of the responses with respect to the methodologies and teaching techniques used by chemistry professors in the different classification groups is presented in Table 35-A. The t-test scores show no significant differences existed with respect to teacher methodology and teaching technique practices between the specialized institutions and the liberal arts colleges, and the specialized institutions and the junior colleges at the 5 per cent level of confidence. In regard to the use of conference quizzes (Statement 6, Table 35), however, the t-test score of 2.127 shows, at the 5 per cent level of confidence,

TABLE 35-A. T-TEST OF SIGNIFICANCE FOR TEACHER METHODOLOGY AND TEACHING TECHNIQUES

	Groups of Institutions Compared					
Methodology and Teaching Technique	J. C. vs. Spec.	L. A. vs. Spec.	Univ. vs. Spec.	Univ. vs. J. C.	Univ. vs. L. A.	L. A. vs. J. C.
(See Table 35)	(1)	(2)	(3)	(4)	(5)	(6)
(1)	0.166	0.596	0.409	0.954	0.401	1.259
(2)	0.531	0.556	0.664	0.354	0.379	0.051
(3)	1.671	1.234	0.540	1.616	1.153	0.738
(4)	1.035	1.554	1.083	0.000	1.131	0.909
(5)	0.042	0.793	0.433	0.615	0.642	1.156
(6)	1.523	1.534	2.127*	1.325	1.675	0.026
(7)	0.640	0.018	0.934	2.585*	2.011*	1.037
(8)	0.042	0.423	1.378	2.369*	1.960	0.763*
(9)	1.844	0.212	0.065	2.055*	0.260	2.032*
(10)	0.260	0.447	1.462	2.858*	1.997	1.168
(11)	0.548	0.083	0.487	1.860	1.037	0.903
(12)	1.035	0.551	0.122	2.350*	1.412	1.043
(13)	0.213	0.120	1.180	1.399	1.846	0.173
(14)	1.104	1.159	0.908	0.201	0.368	0.107
(15)	0.942	1.194	0.134	1.616	2.250*	0.167
(16)	0.813	0.929	1.339	0.576	0.622	0.050
(17)	0.779	0.523	1.074	0.312	0.964	0.476
(18)	0.721	0.231	0.023	1.392	0.482	1.803
(19)	0.132	1.160	1.259	1.790	0.157	1.635
(20)	1.323	1.005	0.580	1.625	1.007	0.734
(21)	0.000	0.796	0.539	0.998	0.902	1.476

*Significant at the 5 per cent level of confidence.

that more university professors make use of conference quizzes than do specialized institution professors.

The t-test scores for statements 10, 7, 8, 9, and 12 in Table 35-A are 2.858, 2.585, 2.369, 2.055, and 2.350, respectively. These t-scores show the following differences between the various college categories at the 5 per cent level of confidence: the junior college professors show a greater utilization of the library for other than textbook readings, series of quizzes and tests, student conferences with faculty members, regular problem assignments, and special topics and reports than university professors. These statistics suggest that junior college professors are offering more self-assistance educational experiences to students than university professors.

The t-test score of 2.011 for statement 7, column (5) in Table 35-A, shows that more liberal arts college professors report a more frequent use of quizzes and tests than university professors. The converse is true with respect to the use of black-box instruments; the t-test score for statement 15 in column (5), Table 35-A is 2.255.

The t-test score for statement 9, column (6), Table 35-A, shows, at the 5 per cent level of confidence, that more junior college professors schedule regular problem assignments than liberal arts professors. The t-test score of 2.858 for statement 10 in Table 35-A, column (4) reveals, at the 5 per cent level of confidence, that more junior college professors assign library readings to students than university professors.

Summary

The survey findings in Tables 34 and 35 reveal that introductory college chemistry professors from all institutions in the sample returns are providing supplementary educational experience to accompany lecture and demonstrations. The college category providing the greatest variety of learning experiences, as evidenced by the data in Tables 34 and 35 and supported by the t-tests in Table 35-A, is the junior college.

CHAPTER VII

REACTION OF PROFESSORS TO STATEMENTS RELATED TO REASONS FOR MAKING COURSE CHANGES, TO FACTORS WHICH PROFESSORS FEEL THAT REDUCE STUDENT INTEREST, AND TO SUGGESTIONS FOR DEVELOPMENT OF ITEMS FOR IMPROVEMENT OF TEACHING

Individual chemistry educators, Robert I. Walter,[201] L. Carrol King,[202] and the panel members of the Advisory Council on College Chemistry (AC_3),[203] allude that current curricular changes in introductory college chemistry are largely due to the following forces: (1) the surfeit of knowledge appearing in the chemical literature and the rapid development of chemistry and other sciences; (2) the recent improvement in high school training in mathematics and the sciences; (3) the impact of the Chemical Bond Approach (CBA), Chemistry Education Materials Study (CHEMS), and Physical Science Study Committee (PSSC) courses; (4) that more equipment and modern equipment is available for instructional use in undergraduate laboratories; and finally, (5) the graduate schools have come to expect a higher level of training during the undergraduate years. The Advisory Council (AC_3) believes that the strongest force behind the

[201]Walter, p. 524.

[202]King, p. 126

[203]Haenisch, "The Content of Introductory College Chemistry," p. 20.

curricular changes currently occurring in the continental United States is the desire of chemistry educators to emphasize the nature of the knowledge obtaining enterprise of the chemist and to take the student to the edge of research. Walter reinforced the emphasis placed upon these forces or curricular change agents by concluding:

> Most teachers respond to these forces by making an effort to bring their students into contact with the frontiers of chemistry, and they make an effort to create for their students a sense of participation in science.[204]

Those previous statements with respect to forces that cause curricula changes were either the personal opinions and allusions of individual chemistry educators or panel members of a committee and were not supported by statistical evidence. The purpose of Parts IV and V of the questionnaire, therefore, was to secure the opinions of a large number of college professors as to what they individually believed to be the principal forces responsible for current curricular changes in first-year college chemistry.

Professor Reactions to a Question Requesting Reasons for Changing the Introductory College Chemistry Course

The response to the question from Part V of the questionnaire, requesting reasons for making course changes (see Table 38), resulted in a tally of twenty-six various reasons for curricula changes. A 53 and 55 per cent response (a possible acceptance of all professors in the sample returns) to items 1 (more equipment and more modern equipment are available for laboratory and instructional use) and 4 (theories of chemistry are constantly changing) in Table 38 reveals that a majority of the respondents believe these two factors to be the principal factors

---

[204]Walter, p. 524.

TABLE 38. TEACHER REACTIONS TO REASONS FOR CHANGING THE INTRODUCTORY COLLEGE CHEMISTRY COURSE

Statements	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
1. The availability of more equipment and more modern equipment for laboratory and instructional use.	42	51	42	54	24	58	5	41	113	53
2. Impact of CBA, CHEMS, PSSC courses.	29	35	33	42	10	24	2	16	74	34
3. The number of chemistry majors is diminishing.	19	23	18	23	12	29	1	8	50	23
4. Theories of chemistry are constantly developing.	41	50	48	62	21	51	7	58	117	55
5. Advent of general chemistry textbooks with a change in emphasis.	31	37	41	53	21	51	5	41	98	46
6. Flood of new information appearing in the chemical literature.	21	25	20	25	13	31	2	16	56	26
7. Large number of students beginning the study of introductory college chemistry and the fact that many of these students are better prepared in terms of high school chemistry and/or mathematics.	36	43	38	49	18	43	3	25	95	45
8. Other (Supplied by Respondents)										
(a) Requirements of American Chemical Society.	1	1	0	0	0	0	0	0	1	0
(b) Science is ever changing. Why should instruction stand still?	1	1	0	0	0	0	0	0	1	0
(c) Revision livens.	1	1	0	0	0	0	0	0	1	0
(d) Present lab is deadening rather than stimulating.	1	1	0	0	0	0	0	0	1	0
(e) Change 5 years ago and need to attempt evaluation.	1	1	0	0	0	0	0	0	1	0
(f) Change often catalyzes interest.	1	1	0	0	0	0	0	0	1	0
(g) Demand of the "Establishment" for more theoretically oriented course.	1	1	0	0	0	0	0	0	1	0
(h) Students are beginning to ask, "Why?"	1	1	0	0	0	0	0	0	1	0
(i) Course becomes stagnant without change.	1	1	0	0	0	0	0	0	1	0
(j) Growing need to integrate and demonstrate unity in science.	0	0	1	1	0	0	0	0	1	0
(k) Student population is changing.	0	0	1	1	0	0	0	0	1	0
(l) More is required by students in higher level courses.	0	0	1	1	0	0	0	0	1	0

TABLE 38. (Continued)

Statements	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
8. Other (continued)										
(m) Student interest is low in the present course.	0	0	1	1	0	0	0	0	1	0
(n) Simple need of instructor to seek constant improvement.	0	0	1	1	0	0	0	0	1	0
(o) Keep up with modern educational trends.	0	0	0	0	1	2	0	0	1	0
(p) Lack of student oriented teaching/inability to communicate the meaning of science.	0	0	0	0	1	2	0	0	1	0
(q) Mainly to give more lab experience.	0	0	0	0	1	2	0	0	1	0
(r) Too much in general chemistry courses.	0	0	0	0	1	2	0	0	1	0
(s) More thoroughly used teaching time, less "scanning".	0	0	0	0	1	2	0	0	1	0

responsible for course changes in first-year college chemistry. In addition, the 46 and 45 per cent responses to items 5 (the advent of general chemistry textbooks with a change in emphasis) and 7 (the large number of students beginning the study of first-year college chemistry who are better prepared in terms of high school chemistry and mathematics) suggest these factors as likely candidates responsible for course changes in introductory college chemistry. To note that the professors from all institutions rejected the influence (per cent approval was 34 or less) of curricula change due to statements 2 (the impact of CBA, CHEMS, and PSSC), 3 (the diminishing number of chemistry majors, and 6 (the flood of new information appearing in the literature) raises several questions since these factors have been frequently mentioned in the literature as chiefly responsible for changes in first-year college chemistry curricula. Specifically, the general objective of introductory college chemistry accepted by professors participating in the survey (see Chapter V, p. 162) is to develop the ability to do critical thinking and the secondary science innovations (CBA, CHEMS, and PSSC) are inquiry oriented. Why have these secondary innovations made little, if any, impact upon the first-year college chemistry course? That only 14 per cent of the introductory college chemistry students have had prior experience in one or more of these secondary science innovations[205] leads one to question the validity of the emphasis being placed on these secondary innovations as college curriculum change agents. Since the data (item 3, All Institutions column, Table 10) reveal only one student in seven in this survey have had experience in one or more of these secondary science innovations

---

[205]See data in Table 10, Chapter IV, p. 102.

prior to enrollment in introductory college chemistry and only 34 per cent of the professors (item 2, All Institutions column, Table 38) agree that the new secondary innovations have had a pronounced effect upon freshman college chemistry, the investigator suggests that the new secondary science innovations have made little impact, in the capacity of curriculum change agents, upon the first year college chemistry curricula in colleges in the sample returns. These innovations, however, show a more pronounced effect upon the liberal arts colleges than the other three college categories as evidenced by a 42 per cent response to statement 2 (impact of CBA, CHEMS, PSSC courses). In additional comments, which were attached to the questionnaire returns, the respondents listed nineteen various reasons for making course change; not one professor mentioned "recent improvement in the teaching of high-school chemistry" nor "the graduate schools have come to expect a higher level of training during the undergraduate years," as a factor.

The lack of majority agreement, as revealed by the data in Table 38, with respect to factors responsible for course change, suggest that professional chemistry educators cannot come to a common agreement as to what forces are really producing curricula changes. One of the marginal comments attached to the questionnaire reinforced this conclusion; this professor wrote, "Why don't people go their way or try their own ideas rather than trying to go by a consensus? A consensus of fools is still a consensus. Teaching of any course, if done with viability, is in constant change. I have probably never taught the same course in the same way. Our day to day innovations in our teaching and research should serve to keep our course modern."

A majority of the respondents (53 per cent response to item 1, Table 38) feel that more equipment and modern equipment have been responsible for changing the introductory chemistry course. The validity of change brought about by the accessibility of new and modern equipment is questioned since the respondents had previously shown a low usage of sophisticated equipment.[206] This is probably true of the upper level chemistry course, but the impact is probably not felt on the introductory level.

Reactions of Professors to Statements of Factors Which They Feel that Reduce Student Interest

That many former introductory college chemistry students complain that the general chemistry course had been a waste of time,[207,208] especially in the laboratory, and only 1 per cent of those students who take freshman college chemistry graduate to become practicing chemists and only one-third of these do post-graduate work leading to a doctorate in chemistry,[209] infers that student interest in first-year college chemistry is less than satisfactory.

The purpose of Part IV of the Questionnaire was to determine what

---

[206]The use of sophisticated equipment other than the single pan balance and the pH meter was shown by the data in All Institutions column in Table 36 to range from a low of 8 per cent to a high of 38 per cent.

[207]Leallyn B. Claggs, "The Brown Experiment in Chemical Education," <u>Journal of Chemical Education</u>, <u>35</u> (1958) p. 170.

[208]Edward L. Haenisch, Editor. <u>Experimental Curricula in Chemistry</u>. A Report of the Advisory Council on <u>College Chemistry Conference</u>. Chicago, Illinois, October, 1963.

[209]Westheimer, p. 93.

TABLE 39. TEACHER REACTIONS TO FACTORS THAT REDUCE INTEREST IN THE INTRODUCTORY CHEMISTRY COURSE

Limiting Factors	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
1. Topics are unrelated to student interest.	44	53	41	53	15	36	8	66	108	50
2. Too much theory.	30	36	24	31	17	41	4	33	75	35
3. Not enough laboratory work.	4	4	10	12	10	24	2	16	26	12
4. Insufficient or inadequate laboratory equipment.	26	31	21	27	12	29	3	25	62	29
5. Lack of library facilities.	2	2	5	6	6	14	1	8	14	6
6. Not enough individual work.	30	36	22	28	14	34	1	8	67	31
7. Too much memory work.	25	30	29	37	15	36	5	41	74	34
8. Subject too formally presented.	23	28	19	24	12	29	5	41	59	27
9. Instructor teaching too many subjects or students.	16	19	26	33	10	24	4	33	56	26
10. Facts taught as ends (products) of science rather than a means (processes) of science.	19	23	17	22	9	21	3	25	48	22
11. Too much teacher dependence on textbook.	9	10	16	20	12	29	4	33	41	19
12. Too much telling - too much teacher domination.	23	28	25	32	18	43	3	25	68	32
13. Failure of instructor to clarify a general principle.	13	15	17	22	6	14	3	25	38	18
14. Failure to use "practical tangibles" in place of "textbook tangibles."	10	12	18	23	8	19	4	33	40	18
15. Too little faculty time - too involved in research or other activities.	13	15	10	12	9	21	4	33	36	16

TABLE 39. (Continued)

Limiting Factors	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
16. Poor instruction by graduate assistants.	22	26	5	6	5	12	3	25	35	16
17. Other (Supplied by Respondents)										
(a) Student interest in grades (e.g. to avoid draft); atmosphere emphasizing grades discourages serious study; interest in "passing" rather than in learning.	2	2	1	1	1	2	0	0	4	2
(b) An introductory chemistry course is hard work and difficult and many students are just not willing to put forth the effort.	5	6	1	1	0	0	0	0	6	3
(c) "Fear" of chemistry-preoccupied idea of students that chemistry is a very difficult course.	1	1	1	1	0	0	0	0	2	1
(d) The lack of training in scientific thinking in their previous education (from K thru 12).	1	1	0	0	0	0	0	0	1	0
(e) Many students are fulfilling a requirement, not taking chemistry by choice - students not committed to a vocation.	2	2	1	1	0	0	0	0	3	1
(f) Topics unrelated to the scientific world in which the student will operate.	1	1	0	0	0	0	0	0	1	0
(g) Some students are not interested in worthwhile endeavors.	1	1	0	0	0	0	0	0	1	0
(h) Insistence of parents on science career for junior.	1	1	0	0	0	0	0	0	1	0
(i) Poor high school preparation in science and especially mathematics.	1	1	2	2	1	2	0	0	4	2

TABLE 39. (Continued)

Limiting Factors	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
17. Other (continued)										
(j) Not enough demonstration to make principles real rather than abstract.	1	1	0	0	0	0	0	0	1	0
(k) Labs have not been as intellectually stimulating as they could be.	1	1	0	0	0	0	0	0	1	0
(l) The difficulty of establishing a perspective of the subject to which the student can relate the subject matter being presented.	1	1	0	0	0	0	0	0	1	0
(m) Freshmen very poorly disciplined and do not keep up with curriculum.	1	1	0	0	0	0	0	0	1	0
(n) Too little feedback or exchange.	1	1	0	0	0	0	0	0	1	0
(o) None of the above apply. Students are busy with other courses.	1	1	0	0	0	0	0	0	1	0
(p) Too many topics in such a short time. Students are overwhelmed.	1	1	0	0	0	0	0	0	0	0
(q) Previous experience with science and the interest of the individual.	0	0	1	1	0	0	0	0	1	0
(r) Too much competition for students time and attention by other courses and campus activities - lack of willingness of students to work seriously.	0	0	4	5	2	5	0	0	6	3
(s) Too much laboratory work.	0	0	1	1	0	0	0	0	1	0
(t) Too much theory too early.	0	0	1	1	0	0	0	0	1	0

TABLE 39. (Continued)

Limiting Factors	Univ.		Lib. Arts		Jr. Coll.		Spec.		All Inst.	
	No.	%	No.	%	No.	%	No.	%	No.	%
17. Other (continued)										
(u) I don't know - certainly varies with the student.	0	0	1	1	0	0	0	0	1	0
(v) Course takes too much application and ability for many.	0	0	1	1	0	0	0	0	1	0
(w) The concepts are frequently difficult for some students. If a student fails to learn something well at the beginning of the course, he will invariably have trouble later.	0	0	1	1	0	0	0	0	1	0
(x) Students want courses that do not necessitate study every day.	0	0	1	1	0	0	0	0	1	0
(y) Professor overworked.	0	0	0	0	1	2	0	0	1	0
(z) People interested in their check and not teaching.	0	0	0	0	1	2	0	0	1	0
(aa) Bad textbooks (books written for amusement of instructors and not for the instruction of students).	0	0	0	0	1	2	0	0	1	0
(bb) Use of the whole gamut of subject materials in a single "Introductory" course.	0	0	0	0	1	2	0	0	1	0
(cc) Prestige seeking by faculty.	0	0	0	0	1	2	0	0	1	0
(dd) You name it and someone will have it.	0	0	0	0	0	0	1	8	1	0

the participating professors in the survey really feel to be the principal factors that tend to limit student interest. Items 1 through 16 in Table 39 were dictated by statements related to student interest in the literature, especially the Advisory Council on College Chemistry publications, and the recommendations of the Questionnaire Validation Committee.

When the respondents were asked to react to statements from the literature search which were frequently quoted as limiting student interest or to list what they felt to be the principal factors responsible for limited student interest in freshman chemistry, the result was forty-six factors including the pre-selected list of sixteen supplied by the investigator. The ensuing data revealed a multitude of reasons; however, only one topic received mutual agreement among all four college classifications--topics are unrelated to student interest (Topic 1, Table 39). The implication is that college professors feel that students lose interest in chemistry because of a lack of interest in the subject matter topics being presented.

The following factors listed in Table 39 were rejected by professors in all categories as being responsible for reducing student interest: (1) too much theory (item 2), (2) too much memory work (item 7), (3) subject too formally presented (item 8), (4) too much telling--too much teacher domination; failure of a teacher to clarify a principle (item 18), (5) failure to use "practical tangibles" in place of textbook tangibles (item 14), (6) too little faculty time (item 15), and (7) poor instruction by graduate students (item 16). That only 42 per cent of the respondents (items 3, 4, 17-r, and 17-s) mentioned the laboratory phase as a factor responsible for low student interest raises a question, especially since dissatisfaction with the laboratory was previously listed as the chief criticism by former students.

Since only item 1 (topics are unrelated to student interest) received a majority rating as being chiefly responsible for low student interest in first-year college chemistry raises several questions. What factors are responsible for low student interest in a general chemistry topic? Is the lack of interest due to the difficulty of the topic content or to the professor's method of presentation? The low percentage response to items 15 (too little faculty time - too involved in research and other activities) and item 16 (poor instruction by graduate assistants) raises questions since the Advisory Council on College Chemistry is of the opinion that too little faculty time and poor instruction by graduate students are the principal factors that are likely to cause the quality of instruction in first-year college chemistry to suffer.[210]

Examination of the survey findings in Table 39 reveals that college professors have indicated forty-six factors which they believe to limit student interest but cannot come to any decisive agreement as to the most influential, leads the investigator to suggest the need for another study of the factors which reduce student interest. Probably the two most honest appraisals offered by the respondents were, "I don't know - - certainly varies with the students," and "You name it and someone will have it."

---

[210]"Big Classes Create Big Problems," Chemical and Engineering News, 41, October 28, 1963, pp. 48-50.

TABLE 40. NUMBER OF TEACHER REACTIONS TO DEVELOPMENT OF ITEMS TO IMPROVE THE TEACHING OF INTRODUCTORY COLLEGE CHEMISTRY

Items for Development	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	A[a]	S[b]	D[c]	A	S	D	A	S	D	A	S	D	A	S	D
A. The development of test-like[d] instruments for discovering the particular needs and interests of students and the selection of contents and teaching procedures to meet those needs and interests.	15	31	27	19	32	18	12	19	10	5	4	2	51	86	57
B. The preparation of tests designed to measure the achievement of students with respect to certain aims not now specifically tested such as understanding the processes or methods of chemistry as well as content and the ability to do critical thinking.	23	38	9	37	25	6	24	10	2	7	3	1	91	76	18
C. The retraining of those people already engaged in the teaching of the introductory college course in chemistry to meet the current trend in science teaching.	25	32	16	32	32	6	24	11	1	6	4	0	87	79	23

TABLE 40. (Continued)

Items for Development	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	A	S	D	A	S	D	A	S	D	A	S	D	A	S	D
D. A revolution in attitudes and methods of teaching (the search for fresh and flexible teaching technique) and in the methods of educating college teachers of chemistry.	37	26	11	40	27	3	21	13	4	6	5	0	104	71	18
E. A shift from the traditional emphasis of stressing the facts and products of the discipline of chemistry to the teaching of the processes of chemistry which will be valuable in all learning long after the facts are forgotten.	43	20	7	42	22	5	25	10	1	7	2	2	117	54	15
F. Other	9	0	0	4	0	0	4	0	0	0	0	0	17	0	0

[a]A - very important

[b]S - some importance

[c]D - not at all important

[d]Inventories and checklists

TABLE 41. PERCENT OF TEACHER REACTIONS OF DEVELOPMENT OF ITEMS TO IMPROVE THE TEACHING OF INTRODUCTORY COLLEGE CHEMISTRY

Items for Development	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	A[a]	S[b]	D[c]	A	S	D	A	S	D	A	S	D	A	S	D
A. The development of test-like instruments for discovering the particular needs and interests of students and the selection of contents and teaching procedures to meet those needs and interests.	18	37	32	24	41	25	29	46	24	41	33	16	24	40	26
B. The preparation of tests designed to measure the achievement of students with respect to certain aims not now specifically tested such as understanding the processes or methods of chemistry as well as content and the ability to do critical thinking.	28	46	10	48	32	7	58	24	4	58	25	8	42	35	8
C. The retraining of those people already engaged in the teaching of the introductory college course in chemistry to meet the current trend in science teaching.	30	39	19	41	41	7	58	26	2	50	33	0	41	37	10
D. A revolution in attitudes and methods of teaching (the search for fresh and flexible teaching technique) and in the methods of educating college teachers of chemistry.	45	31	13	51	35	3	51	31	9	50	41	0	49	33	8
E. A shift from the traditional emphasis of stressing the facts and products of the discipline of chemistry to the															

TABLE 41. (Continued)

Items for Development	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	A	S	D	A	S	D	A	S	D	A	S	D	A	S	D
teaching of the processes of chemistry which will be valuable in all learning long after the facts are forgotten.	52	24	8	54	28	6	60	24	2	58	16	16	55	25	7
F. Other (Supplied by Respondents)															
1. Change high school chemistry courses so that they teach a few areas well, i.e., atomic structure, gas laws, acid-base theory, and leave all else to college courses.	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
2. Hammond Curriculum.	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
3. The ACS test could measure both the achievements of students and the teachers.	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
4. Teacher dedication.	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
5. Improvement of laboratory exercises to illustrate pertinent points.	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
6. A revised standard for what are appropriate and attainable goals.	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
7. A good 12 week qualitative analysis course ties chemistry together especially on requiring balanced equations for all reactions possible.	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0
8. Readable textbooks need to be written.	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0
9. Teach (a) the art of discriminatory thinking and (b) the necessary factual bases.	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0

TABLE 41. (Continued)

Items for Development	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	A	S	D	A	S	D	A	S	D	A	S	D	A	S	D
F. Other (continued)															
10. A very strong involvement—and a not direct one—of senior faculty participation in all levels of courses.	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
11. Stop teaching course as if for chemistry majors only.	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
12. Beware of eliminating descriptive material to the extent that the students don't understand the behavior of matter on an everyday basis.	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
13. Training of teachers for 2 year colleges is of particular importance.	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
14. Methods of teacher-student interaction. Rapid growth of our institutions and many others leave numerous students without personal relations with faculty.	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
15. Development of teaching procedures to meet the needs and interests.	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0

[a]A - very important

[b]S - some importance

[c]D - not at all important

Professor Responses to Statements of Suggestions for Improvement

The purpose of Part IV, Section 2 of the Questionnaire was to obtain ideas from college chemistry professors that could possibly lead to the improvement of the teaching of general college chemistry. The five pre-selected items listed in Table 40 were dictated by the Validation Committee. The per cent response and the additional comments are listed in Table 41.

To assist in the interpretation of the data in Table 40, the following procedure was designed to evaluate the teacher responses to the pre-selected statements related to suggestions for improvement of the teaching of introductory college chemistry. Each topic in Table 40 was evaluated in Table 42 by assigning the following numerical values to the three possible responses for each item: Column 1, three points; Column 2, two points; Column 3, one point. The column score was calculated by multiplying the number of respondents checking that topic by the number of points assigned to the column. The number of points for each column was added for each topic to get an actual score. The highest possible score was calculated by multiplying the number of checks times three. The percentage-of-importance score was determined by dividing the actual score by the highest possible score and multiplying by 100.

Example: Topic "one" is checked by 194 professors. Thus 194 x 3 = 582 = highest possible score.
Response A was checked by 51 professors, S by 86 professors, and D by 57 professors.
Thus actual score = (51 x 3) + (86 x 2) + (57 x 1) = 382
Percentage-of-importance score = $\frac{382 \times 100}{582}$ = 66%

TABLE 42. PERCENTAGE-OF-IMPORTANCE SCORES FOR STATEMENTS RELATED TO THE IMPROVEMENT OF TEACHING OF INTRODUCTORY COLLEGE CHEMISTRY

Topic from Table 40	Responses* A (1)	S (2)	D (3)	Number of Checks	Possible Score	Actual Score	Percentage-of-Importance Score
A	51	86	57	194	582	382	66
B	91	76	18	185	555	443	80
C	87	79	23	181	543	422	78
D	104	71	18	193	579	472	82
E	117	54	15	186	558	474	85

*All Institutions Column, Table 40.

The data in the percentage-of-importance score column in Table 42 show a general acceptance by all respondents for the five pre-selected statements which suggested ideas for improvement in the teaching of freshman chemistry. Those data, including the additional remarks listed under the topic entitled "other" in Table 41, gave sufficient evidence to justify a revolution in attitudes and methods of teaching freshman chemistry (Topic D) and in the methods of educating college teachers of chemistry even to the point of retraining those people presently engaged in teaching first-year college chemistry (Topic C). The implication of the need to teach chemistry as a process is very strong as revealed by the 85 percentage-of-importance score for Topic E in Table 42. That 24 per cent of the respondents assigned a very important rating to Topic A in Table 41 (The development of test-like instruments for discovering the particular needs and interests of students and the selection of content and teaching procedure to meet those needs and interests), and 40 per cent assessed Topic A a rating of some importance suggested an indecision with respect to Topic A. This indecision is probably explained by one of the respondents in his evaluation of Topic A when he wrote: "I consider the development of teaching procedures to meet the needs and interest to be very important. The development of test-like instruments to do this I cannot conceive." Additional comments were also offered which suggested alternate methods to help increase student interest. One professor asked for the development of teaching procedures to meet student needs and interests. Another professor suggested the need for methods to achieve teacher-student interactions. A third advocated the adoption of the Hammond Curriculum and still another remarked, "The most difficult 'nut' to crack is the professor's notion that what he learned and taught for many years should still be the core of his teaching." The 80 percentage-of-importance score rating for Topic B in Table 42

TABLE 42-A. T-TEST OF SIGNIFICANCE FOR TEACHER REACTIONS TO ITEMS SUGGESTING THE IMPROVEMENT OF TEACHING OF GENERAL CHEMISTRY

Topic	J. C. vs. Spec.	L. A. vs. Spec.	Univ. vs. Spec.	Univ. vs. J. C.	Univ. vs. L. A.	L. A. vs. J. C.
Degrees of Freedom	51	87	92	121	157	116
Ideas for Improvement (See Tables 41 and 42)	t-test (1)	(2)	(3)	(4)	(5)	(6)
A	1.411	0.676	1.135	0.140	0.969	1.018
B	0.461	0.122	0.752	0.981	1.293	0.960
C	0.124	1.348	1.805	2.918*	1.402	1.976*
D	0.421	0.020	0.598	0.306	1.204	0.715
E	1.012	0.434	0.573	0.657	0.346	1.003

*Significant at the 5 per cent level of confidence.

reveals that the participating college professors realize the need for the preparation of tests designed to measure the achievement of students with respect to certain aims not now specifically tested such as understanding the processes or methods of chemistry as well as content and the ability to do critical thinking.

In general, all four classifications were in mutual agreement regarding the five statements in Table 40 related to the improvement of the teaching of introductory college chemistry. The t-test scores of 2.918 and 1.976 in Table 42-A, statement C, columns 4 and 6, however, show that more junior college professors than university and liberal arts college professors favor the urgent need for retraining of the current professors of freshman chemistry at the 5 per cent level of confidence. This means that a higher percentage of junior college professors are in favor of retraining of their colleagues than are university and liberal arts professors. With respect to the other statements listed in Table 42-A, the t-test show that the four classifications were in mutual agreement.

CHAPTER VIII

COURSE CONTENT TOPICS, RECITATION TOPICS AND LABORATORY EXPERIMENTS

The cooperating institutions were asked to supply the investigator with syllabi or course outlines of their introductory college chemistry courses. The response to a request for a description of lecture topics was less than 8 per cent (fifteen syllabi were received).

Each lecture topic on each syllabi (or course outline) was interpreted and identified with a specific topic or subtopic. The examination of syllabi and course outline topics showed the major subject matter areas to fall into nine major areas. Each of these was further subdivided as shown in Table 43.

The data presented in Table 43 have to be interpreted in the following manner: Whenever a topic could be classified under more than one heading, it was classified under the most specific heading. Arbitrarily, each successive heading in Table 43 is presumed to be, by its relative position, more specific than the preceding heading. Thus, for example, a topic dealing with the Nucleus and Radioactivity was placed under, "Atomic Structure," rather than under, "Nuclear Chemistry," or "Nuclear Structure." Further, a topic dealing with Balancing Oxidation and Reduction Equations was classified under "Oxidation-Reduction Reaction" rather

TABLE 43. NUMBER OF MAJOR LECTURE TOPICS APPEARING ON 15 FIRST-YEAR COLLEGE CHEMISTRY COURSE SYLLABI

Topic	Number of Responses					Range of Lectures per Topic	Average Number of Lectures per Topic
	Univ.	Lib. Arts	Jr. Coll.	Spec.	Total		
1. Atomic Structure	6	5	3	1	15	1-15	7.0
A. Atomic Nature of Matter	3	3	2	1	9	1-3	2.0
1. Atomic Theory to Dalton							
2. Dalton's Atomic Hypothesis							
B. Modern Views on Atomic Structure	4	2	2	1	9	2-15	7.0
1. History of the Quantum Concept[a]							
2. Schrodinger's Wave Equation							
3. Electron Cloud and Ionization[b]							
4. Quantum Mechanics and Picture of Atom							
5. Atomic Number and Isotopes							
C. Nuclear Structure and Radioactivity	1	2	3	0	6	1-9	5.0
1. Nuclear Structure and Properties							
2. Nuclear Models							
3. Nucleus and Radioactivity							
4. Nuclear Stability and Binding Energy							
5. Nuclear Reactions: fission and fusion							
6. Rate of Radioactive Decay							
7. Application of Radioisotopes in Chemistry							
8. Atomic Energy for Peace							
2. Chemical Bonding	6	5	3	1	15	1-15	8.5
A. Chemical Bonding and Molecular Structure	6	5	3	1	15	3-15	4.6
1. Fundamentals of Variation Theory							
2. Molecular Orbital Theory							
3. Valence Bond Theory							
4. Thermodynamic Aspects[c]							
5. Electronic Aspects[d]							
a. Ionic Bonding							
b. Covalent Bonding							
c. Metallic Bonding							
B. Bonding in Coordination Compounds	1	1	0	0	1	2	2.0
1. Valence Bond Theory							

TABLE 43. (Continued)

Topic	Number of Responses					Range of Lectures per Topic	Average Number of Lectures per Topic
	Univ.	Lib. Arts	Jr. Coll.	Spec.	Total		
2. Chemical Bonding (Continued)							
B. Bonding in Coordination Compounds							
2. Crystal Field Theory							
3. Ligand Field Theory							
C. The Nature of Compounds	0	1	0	0	1	1	1.0
1. Gay-Lussac's Law of Combining Volumes							
2. Cannizaro and Avogadro's Hypothesis							
D. Molecular Compounds	3	2	1	0	6	10	1.7
1. Formula Types[e]							
2. Ionic Compounds[f]							
3. States of Matter and Solutions	6	5	3	1	15	1-10	6.4
A. State of Matter	6	5	3	1	15	1-10	3.0
1. Gases[g]							
2. Solids[h]							
3. Liquids[i]							
B. Properties of Solutions	5	1	2	0	8	1-6	2.0
1. Solutions: activities and colligative properties							
2. Ideal Solutions[j]							
3. Non-ideal Solution: criteria and Causes							
4. Stability[k]							
4. Stoichiometry	6	5	3	1	15	1-9	2.0
A. Atomic Weights[l]							
B. Mole Concept							
C. Molecular Weight Calculations[m]							
D. Chemical Equations							
1. Significance							
2. Types: complete, ionic, essentially ionic							
E. Balancing Equations							
F. Yield Problems (gas yield at STP)							
G. Atomic Weight from Reaction							

TABLE 43. (Continued)

Topic	Number of Responses					Range of Lectures per Topic	Average Number of Lectures per Topic
	Univ.	Lib. Arts	Jr. Coll.	Spec.	Total		
4. Stoichiometry (Continued)							
H. Chemical Factor							
I. Indirect Calculations							
J. Concentrations of Solutions							
1. Methods of Stating Concentration							
2. Preparation and dilution of solutions							
3. Reactions and Stoichiometry of Solutions							
5. Chemical Equilibrium	6	5	3	1	15	1-13	6.4
A. General Aspects	4	2	3	1	10	1-13	2.6
1. Reversibility, Spontaneous, independence of starting point							
2. Equilibrium Constant, Law of Mass Action, Conventions Employed							
3. External Conditions and Equilibria							
4. Corrections for Non-ideal Behavior							
5. Equilibrium State from Initial Conditions							
B. Ionic Equilibrium in Aqueous Solution	6	5	3	1	15	1-6	3.6
1. Sparingly Soluble Salts[n]							
2. Acids and Bases[o]							
3. Acid-Base Reaction							
4. Auto-dissociation of solvent: K_a, K_i, pH							
5. Hydrolysis							
6. Neutralization and Titration[p]							
7. Multistate Equilibria							
C. Oxidation-Reduction Reaction	2	2	3	1	8	1-6	3.6
1. Definition of Terms							
2. Relation to Cell Processes							
3. Balancing Oxidation-Reduction equations							
a. Half-cell Method							
b. Oxidation Number Method							

TABLE 43. (Continued)

Topic	Number of Responses					Range of Lectures per Topic	Average Number of Lectures per Topic
	Univ.	Lib. Arts	Jr. Coll.	Spec.	Total		
5. Chemical Equilibrium (Continued)							
C. Oxidation-Reduction Reaction							
4. Electro-chemical Cells[q]							
5. Oxidation-Reduction Titrations							
6. Chemical Kinetics	6	5	3	1	15	1-9	3.8
A. Concentration and Rate (Rate Laws)							
B. Reaction Mechanisms							
C. Models for Reaction (Collision Models for Reaction)							
D. Reaction and Equilibrium							
E. Collision Theory							
F. Temperature Dependence on Reaction Rate							
G. Catalysis							
7. Chemical Reactivity	6	5	3	1	15	1-20	4.8
A. Chemical Reactions	4	2	3	1	10	1-2	1.5
B. Thermodynamics	6	3	2	1	15	1-20	4.9
1. Definitions Reviewed and Calculations of W and Q							
2. First Law (Energy Changes in simple processes, Thermochemistry[r]							
3. Second Law[s]							
4. Third Law: Entropies							
5. Free Energy							
a. Delta G and Equilibrium Constant							
b. Electrochemistry (Delta G and Electrochemical Cells)							
c. Delta G and Temperature Dependence of equilibrium							
d. Gibbs-Helmholtz Equation							
e. Colligative Properties Revisited							
8. Descriptive Chemistry	4	2	3	1	10	1-2	1.5
A. Metallic Elements	4	1	3	1	9	3-8	5.0
1. Metallurgy							

TABLE 43. (Continued)

Topic	Number of Responses					Range of Lectures per Topic	Average Number of Lectures per Topic
	Univ.	Lib. Arts	Jr. Coll.	Spec.	Total		
8. Descriptive Chemistry (Continued)							
A. Metallic Elements							
2. Active Metals of Main Group I, II, III							
3. Post-transistion Elements of Main Groups III, IV, V							
4. Transistion Elements (d-orbital, lanthanide, actinide)							
5. Cation Analysis							
B. Non-metallic Elements	6	5	3	1	15	1-11	3.3
1. Noble Gases							
2. Halogen Elements							
3. Sulfur and oxides							
4. Group V Non-metals							
5. Boron, Silicon, Germanium							
6. Hydrogen and Hydrides							
C. Hydrogen, Oxygen, and Water	2	0	2	0	4	1	1.0
D. Inorganic Chemistry	3	3	3	1	10	1-10	3.5
1. Periodic Relationships[t]							
2. Transition Metal Complexes: Magnetic and Optical Properties							
3. Certain oxides and Hydroxides							
E. Organic Chemistry[u]	3	2	3	0	8	3-12	7.0
9. Other Topics							
A. Basic Information (Understanding the Language of Science)	3	2	3	0	8	1-5	3.0
1. Working Definitions[v]							
B. Nomenclature of Compounds	1	2	3	0	5	1-2	1.4
1. Rules for Assigning Oxidation Number							
2. Naming Binary Compounds							
3. Naming Compounds of High Order							
C. Biological Chemistry[w]	3	0	0	0	3	1-10	3.0
D. Colloidal Chemistry	0	2	0	0	2	3	3.0

TABLE 43. (Continued)

[a]Planck's hypothesis, specific heat of solids, photoelectric effect, Bohr theory, and new picture: de Broglie, Compton, Heisenberg.

[b]Auf-Bau principle, Pauli principle, sheilding, ionization potential, electron affinity, orbitals, electronegativity.

[c]Bond energies, bond length, bond angles.

[d]Ionic crystals, X-ray determination, some common structures, lattice stabilities energy, Born-Haber Cycle, valence stability, Pauling's rules and ratio.

[e]Empirical, molecular, and structural.

[f]Formulas, types of ions: simple, compound, complex.

[g]Ideal Gas Laws, simple kinetic theory, real gases.

[h]Forces in crystals, determination of structure, classification of structure.

[i]Forces in liquids, phase changes.

[j]Raoult's law, boiling point and freezing point of solutions, volatile solutes and distillation.

[k]Conditions influencing, Le Chatelier's principle.

[l]Atomic symbols and significance, multiple properties, and equivalent proportions. Rule of greatest simplicity, Avogadro's hypothesis, DuLong and Petit, Modern Methods.

[m]Calculations: molecular weight, per cent composition, formula from per cent composition.

[n]Solubility product (K_{sp}), common-ion effect, selective precipitation.

[o]Arrhenius theory, Bronsted-Lowry theory, Lewis theory.

[p]Dilution effect, reaction effect, buffer effect.

[q]Current effects, voltage effects, Nernst equation.

[r]Energy changes in simple processes, internal energy (delta E), enthalapy or heat content (delta H).

TABLE 43. (Continued)

[s]Entropy, spontaneity, free energy, definition of entropy (delta S).

[t]Arrangement of periodic table, variation of properties, conductive properties, radius, acidity of binary acids, oxy-acids.

[u]Carbon and organic compounds: alakanes, functional groups, aromatic compounds, isomerism.

[v]Chemistry, matter-division and types of properties, systems (open, closed, isolated and conserved), energy, heat, basic concepts, measurements, and substances.

[w]Biopolymers, enzyme catalysis, antibiotics, chemistry and living.

than the topic, "Stoichiometry."

Ambiguities in Table 43, where encountered have been explained by footnotes. Thus, for example, note q in Table 43 (electro-chemical cells) indicates that electrochemistry is classified under "Oxidation-Reduction Reactions" while other chemical reactions were classified under the major topic "Chemical Reactivity," or its subtopic, "Thermodynamics." Hence, the study of atomic weight calculations would not be classified under "Atomic Structure," but under "Stoichiometry."

The college and classification type, in all fifteen cases, were indicated by each respondent; six institutions were from the university category, five from the liberal arts, three from junior college, and one from specialized institutions. Hence, with respect to the classification distribution of the fifteen institutions of higher learning responding, the sample was weighted slightly in favor of universities (40 per cent). One-third of the replies were from liberal arts colleges, one-fifth from junior colleges, and one reply from a specialized institution.

Since the data presented in Table 43 represent summaries of course outlines and syllabi, some topics from individual syllabi became eclipsed in the calculations and do not appear explicitly in the tabulations. The counts of specific topics by institution types shown in the table represent the number of times that specific topic was encountered. Those counts, then, represent relative emphases within the course. Course outlines from two of the responding institutions showed definite departure from the usual course pattern. They emphasized one or more closely defined areas such as thermodynamics (12 and 20 lectures), Quantum Theory (15 lectures), or Chemical Bonding (15 lectures). The syllabi and course outlines differed so greatly that the investigator was unable to devise a satisfactory method to compare the sequence order in which the topics were presented; for example, Nuclear Chemistry was taught across the spectrum of the academic year. Many professors attached notes to the questionnaire explaining that they did not have time to prepare a syllabus or stated that the syllabus of the course was changing so rapidly that it would not be representative of the course currently offered.

In addition to the description of lecture topics, eight[211] of the fifteen responding institutions included outline descriptions of their recitation sessions (i.e., problem sessions, problem discussions, pre-laboratory quizzes, homework, examinations, and reviews); six[212] of these respondents discussed their laboratory activities. A description of these topics is presented in Table 44. Those eight syllabi reveal that some colleges and universities are, in addition to lecture and laboratory, devoting from one to two hours per week to recitation sessions. Major topic number 5 (Stoichiometry) in Table 43 and the Topic Titles listed in Table 44 suggest that college chemistry professors are placing an important emphasis upon stoichiometry, either in recitation sessions or lecture sections. That eight of the fifteen responding institutions have regularly scheduled problem sessions reveals the sample to be weighted slightly in favor of recitation sessions. Two of those eight institu-

[211]Of the eight responding institutions, two included recitation sessions as an integral part of the lecture phase of the course; the remaining six included the recitation sessions as a part of the laboratory activity, either pre-laboratory or post-laboratory.

[212]One institution listed the laboratory manual title but failed to list the experiments performed; another institution listed the page numbers to their own departmental laboratory manual but failed to send a description or titles of the experiments used.

TABLE 44. TOPICS COVERED IN A ONE OR TWO HOUR RECITATION SESSION

Topic	Number of Institutions Responding					Range of Sessions per Topic (8 Syllabi)	Total Hours on Topic (8 Inst.)	Average Number of Hours per Topic
	Univ.	Lib. Arts	Jr. Coll.	Spec.	Total			
1. Measurements: density and specific gravity.	0	3	2	0	5	1-2	5	1
2. Atomic weights, molecular weights and moles.	1	3	2	0	6	1-2	10	1.7
3. Composition Calculations, Calculations from Chemical Equations.	0	3	2	0	5	1	5	1
4. Temperature measurement and measurement of gases.	1	3	1	0	5	1-3	7	1.4
5. Molecular weights of gases.	1	3	1	0	5	1	5	1
6. Electrochemistry.	1	3	1	0	5	1	5	1
7. Equivalent weight, valence, oxidation state.	0	2	2	0	4	1-2	7	1.7
8. Expressing concentrations of solutions and properties of solutions.	0	2	2	0	4	1-2	7	1.7
9. Reactions involving normal solutions.	0	2	2	0	4	1	4	1
10. Chemical equilibrium.	3	3	2	0	8	1-3	12	1.5
11. Ionic equilibrium.	1	3	2	0	6	1	6	1
12. Solubility Product and precipitation.	1	3	2	0	6	1-2	7	1.2
13. Review of principles, including topics suggested by students.	0	0	1	0	1	1	1	1
14. Basic concepts[a] of mathematics in chemistry.	0	3	2	0	5	1	5	1
15. Chemical nomenclature.	0	3	1	0	4	1-2	5	1.3
16. Writing and balancing equations.	1	3	2	0	6	1-2	9	1.5
17. Graphical relationships.	0	1	0	1	2	1	2	1
18. Slide rule.	0	0	2	0	2	2-3	5	2.5
19. Prediction of common chemical reactions.	1	3	2	0	6	1	6	1
20. Percentage composition and stochiometric problems from chemical equations.	0	0	2	0	2	1	2	1

TABLE 44. (Continued)

Topic	Number of Institutions Responding					Range of Sessions per Topic (8 Syllabi)	Total Hours on Topic (8 Inst.)	Average Number of Hours per Topic
	Univ.	Lib. Arts	Jr. Coll.	Spec.	Total			
21. Colorimetry and problems on heat energy, specific heat, heating and cooling curves, heat of fusion, heat of vaporization, (Chemical Thermodynamics).	2	3	2	0	7	1-5	12	1.7
22. Hydrogen ion concentration and pH.	2	3	1	0	6	1-2	8	1.3
23. Colligative properties of solutions including freezing point depression and boiling point elevation.	1	3	1	0	5	1-3	10	2
24. Oxidation and reduction equations.	2	3	2	0	7	1-2	8	1.1
25. Writing of ionic equations, prediction of ionic and redox equations.	2	3	1	0	6	1-2	8	1.3
26. Electrochemical and electrolytic cells.	2	3	1	0	6	1-2	7	1.2
27. Writing nuclear equations and energy changes in nuclear reactions, half-life.	0	3	0	0	3	1-2	4	1.3
28. Reading Assignment.	1	0	0	0	1	15	15	15
29. Atomic Structure and Quantum Theory.	1	0	0	0	1	4		4
30. Solids.[b]	2	0	0	0	2	2-3	5	2.5
31. Chemical Kinetics.	1	0	0	0	1	3	3	3
32. Reaction Rates.	1	3	0	0	4	2	8	2
33. Cation Analysis.	1	1	0	0	2	1-3	4	2
34. Organic Chemistry.	0	1	1	0	2	1-3	4	2
35. Periodic Properties.[c]	3	3	0	0	6	1-9	28	4.7
36. Chemical Bonds.[d]	1	1	0	0	2	1-3	4	2

[a] Measurement, metric systems, temperature scales, exponential notations, significant figures, and logarithms.

[b] Crystals, lattice type, lattice energy.

[c] Periodic relationships and properties; transistion metal and coordination compounds.

[d] Valence Bond Theory, bond energies, bond lengths, polarity, geometry, resonance.

tions scheduled two-hour periods for problem sessions and quizzes while the remaining six allotted a period of one hour. Three institutions used the two one-hour lecture and one one-hour recitation schedule; two institutions used a three one-hour lecture and one two-hour recitation schedule, while the remaining three institutions used the three one-hour lecture and the one one-hour recitation period schedule. The data shown in Table 43 were collected from only 15 syllabi; this is an insufficient number to determine a trend since it represents less than a 10 per cent response. The variation and differences found in the previously discussed syllabi lead the investigator to suggest the need for another study to determine the nature of and the extent of usage of recitation sessions. That 86 per cent of the responding institutions offer problem assignments (see Table 35) without any further description or additional comments adds further support to the need for the study of recitation sessions.

Only in a few cases did the participants in the study supply the investigator with textbook titles, laboratory manual titles, and supplementary book titles. In addition to the fifteen professors who sent course syllabi, three professors listed lecture textbook titles (a total of eighteen textbooks and fourteen different titles). Ten professors (six of these sent syllabi or outlines) listed the laboratory manual titles (three departments had written their own laboratory texts)[213] and eight professors listed supplementary reading materials (books, paper-

---

[213]Additional comments to the questionnaire indicated that one department used a laboratory manual published by a commercial publisher; another stated that their department was encouraged to pursue AC_3 experiments; and another remarked, "Our course is an 'introduction to Scientific Laboratory' in which the students learn to make precise measurements with first class equipment, the specific skills learned are considered secondary," and a fourth professor mentioned that the laboratory manual was supplemented.

TABLE 45. TEXTBOOKS, SUPPLEMENTARY TEXTBOOKS, AND LABORATORY MANUALS

Author	Title	Publisher and Date
Main Textbooks		
Audrey Companion	Chemical Bonding	McGraw Hill, 1964
Harry B. Gray and G. P. Haight, Jr.	Basic Principles of Chemistry	W. A. Benjamin Co.
Donald C. Gregg	Principles of Chemistry	Allyn and Bacon, 2nd ed., 1963
Morris Hein	Foundation of College Chemistry	Dickinson Publishing Co., Inc., 1st ed., 1967
J. H. Hildebrand and R. E. Powell	Principles of Chemistry	Macmillan Co., 1964
G. Brooks King and W. E. Caldwell	College Chemistry	American Book Company
Bruce Mahan	College Chemistry	Addison-Wesley Publishing Company
Bruce Mahan	University Chemistry	Addison-Wesley Publishing Company, 1st ed., 1965
W. L. Masterson and E. J. Slowinski	Chemical Principles	W. B. Saunders, 1966
William H. Nebergall, et al.	General Chemistry	D. C. Heath and Company, 1963
Rodney L. Olsen	Inorganic Nomenclature	Burgess Publishing Company, 1st ed., 1967
S. Young Tyree and Kerro Knox	Textbook of Inorganic Chemistry	Macmillan Company, 1961
J. Nelson Shaw	College Chemistry	Charles E. Merrill Books, Inc., 1966
M. J. Sienko and R. A. Plane	Chemistry	McGraw Hill Book Co., 3rd ed., 1966
Supplements		
W. E. Addison	Structural Principles of Inorganic Compounds	Wiley, 1961
Allen J. Bard	Chemical Equilibrium	Harper and Row, 1966
Gordon Barrow	Structure of Molecules	W. A. Benjamin Publishing Company
Gordon Barrow, et al.	Understanding Chemistry	Volumes I-V, W. A. Benjamin, Inc., 1967
Robert Bauman	Introduction to Equilibrium Thermodynamics	Prentice-Hall, Inc.
Bradner and Susskind	Atoms and Energy	Litton Instructional Materials, 1966

TABLE 45. (Continued)

Author	Title	Publisher and Date
Bradner and Susskind	The Electromagnetic Spectrum	Litton Instructional Materials, 1966
Herman T. Briscoe	College Chemistry	Houghton, 1951
James N. Butler	pH and Solubility Calculation	Addison Wesley, 1964
Gregory Choppin	Nuclei and Radio-activity	W. A. Benjamin, Inc., 1964
C. E. Dull, et al.	Modern Chemistry	Holt, Rinehart and Winston, 1962
Harry B. Gray	Electrons and Chemical Bonding	W. A. Benjamin, Inc., paperback ed., 1964
Robin M. Hochstrasser	Behavior of Electrons in Atoms	W. A. Benjamin, Inc., paperback ed., 1964
Edward L. King	How Chemical Reactions Occur	W. A. Benjamin, 1963
J. J. Lagowski	The Structure of Atoms	Houghton Mifflin, 1964
Charles E. Mortimer	Chemistry-A Conceptual Approach	Reinhold Publishing Co., 1967
W. C. Pierce, E. L. Haenisch, and D. T. Sawyer	Quantitative Analysis	John Wiley and Sons, 1958
Beckman Schaum and Joel L. Rosenberg	Theory and Problems of College Chemistry	Schaum Publishing Co., 1958
Glenn T. Seaborg	Man-Made Transuranium Elements	Prentice-Hall, Inc., 1963
D. K. Sebera	Electronic Structure and Chemical Bonding	Blaidsell, 1964
Michell J. Sienko	Equilibrium: Freshman Chemistry Problems and How to Solve Them	W. A. Benjamin, 1964
Staff Prepared (5)	Chemistry Supplements and Problem Books	
Jurg Waser	Basic Chemical Thermodynamics	W. A. Benjamin, 1966
Jay A. Young	General Chemistry	Prentice-Hall, 1963
<u>Laboratory Manuals</u>		
W. M. Latimer and R. E. Powell	A Laboratory Course in General Chemistry	Macmillan, 1964
Lawrence E. Conroy and R. S. Tobias	General Chemistry Laboratory Operations	Macmillan, 1965
Harper W. Frantz	Laboratory Study of Chemical Principles	W. H. Freeman and Co., Second ed., 1956

TABLE 45. (Continued)

Author	Title	Publisher and Date
Lloyd E. Malm and Harper W. Frantz	College Chemistry in the Laboratory	W. H. Freeman and Co., #1 (1950) and #2 (1954)
Martin V. McGill and G. M. Bradbury	Chemistry Guide and Laboratory Activities	Lyons and Carnahan, 1964
W. C. Pierce, E. L. Haenisch, and D. T. Sawyer	Quantitative Analysis	John Wiley and Sons, 4th ed., 1958
C. H. Sorum	Introduction to Semi-micro Qualitative Analysis	Prentice-Hall, 4th ed., 1967
Staff prepared	Laboratory Experiments for Chemistry	
Staff prepared	Laboratory Manual	
Staff prepared	Laboratory Manual for Chemistry	
George W. Watt, et al.	Chemistry in the Laboratory	W. W. Norton and Co., Inc. 1964

backs, and departmental supplements). Two respondents indicated that their respective departments had written course supplements specifically designed for student assistance. A list of the textbooks, supplementary readings, and laboratory manuals used by the responding institutions is tabulated in Table 45. Since less than 10 per cent of the professors mentioned the titles of the textbooks and less than 4 per cent mentioned the names of the laboratory manuals, the percentage use of each textbook within the sample was not listed. The data in Table 45 reveal the following use of printed materials: eighteen textbooks (fourteen different titles) from eighteen institutions; twenty-four supplementary books from eight institutions; and eleven laboratory manuals (three were staff prepared) from ten institutions (only six of these sent syllabi which described their laboratory procedure and activities).

Six of the fifteen respondents included an outline of the laboratory experiments used. The data shown in Table 46 show that those outlines include a variety of laboratory experiences. Those data also reveal that each of the six responding institutions was teaching its own individual laboratory course. The differences in choices of laboratory experiments and the schedule sequence in which they occur indicates variety. Since the response to the survey was low[214] (six course syllabi from a total of 212 responding institutions) with respect to the description of a laboratory activities and since laboratory experiments should be an integral part of the first-year college chemistry course, the investigator believes these few practices to be varied enough to justify the statement for the need of a study of laboratory practices.

The Journal of Chemical Education (September issue each year) and Chemical and Engineering News[215] reveal numerous introductory college chemistry textbooks of varying difficulty have been recently written or revised. The investigator's review[216] of these aforementioned books revealed introductory college chemistry topics to be presented at different levels of difficulty and in random sequence of arrangements. A logical sequence of topics is apparently difficult to ascertain, and

---

[214]Those data in Table 45 reflect the listing of the titles of laboratory texts from ten colleges. Since four colleges listed titles of the laboratory manuals without elaborating on the description of activities, only six syllabi were used.

[215]"Chemical Publishers Push Teaching Aids," Chemical and Engineering News, 46, August 19, 1968, pp. 32-35.

[216]B C Dodson and George Castleberry, "A comparison of the One-year High-School and the Freshman College General Chemistry Textbooks," An unpublished survey performed under the direction of Dr. John W. Renner, University of Oklahoma, Norman, 1966.

TABLE 46. LABORATORY EXPERIMENTS IN INTRODUCTORY COLLEGE CHEMISTRY

Assignment	Title of Experiments	Periods in Weeks Devoted to Experiment
1	1. Analytical Balance.	1
	2. Slide Rule Instruction.	1
	3. Introductory Laboratory Technique.	1
	4. Weights and Measurement Plus Unknown.	1
	5. Bunsen Burner, Metric System.	1
	6. Laboratory Techniques, Metric System, and Indirect Measurement.	1
2	1. Laboratory Burner, Glassworking, Determination of a Chemical Formula.	1
	2. Physical Properties of Substances and the Analytical Balance.	1
	3. Glassworking.	1
	4. Separation and Determination of the Components of a Mixture.	1
	5. Density, Physical and Chemical Properties.	1
	6. Separating Mixtures, Breaking Up Compounds, Physical and Chemical Change, Law of Conservation of Energy, and Change in Heated Metals.	1
3	1. Law of DuLong and Petit.	1
	2. Chemical Properties of Substances and Unknown Weights.	1
	3. Per cent Composition.	1
	4. Observing Reactions and Breaking Up Compounds.	1
	5. Starting Growth of Crystals.	1
	6. Analysis of an Iron Solution.	1
4	1. Chemical and Physical Changes.	1
	2. Molal Volume of a Gas.	1
	3. Molal Volume of Nitrogen.	2
	4. Growth of an Alum Crystal.	1
	5. Preparation and Properties of Oxygen.	1
	6. Identification of Salts by Use of Reaction Rules.	1
5	1. Law of Multiple Proportions.	1
	2. Molecular Weight by Vapor Density.	2
	3. Molecular Weight of a Gas.	1
	4. Preparation and Study of Oxygen, Oxygen Generation and Composition of Air.	1

TABLE 46. (Continued)

Assignment	Title of Experiments	Periods in Weeks Devoted to Experiment
	5. Charles' Law and Option.	1
	6. Chemical Reaction and Chemical Equation.	1
	1. Calculations Involving Redox Reactions.	1
	2. Reduction of Oxides.	1
	3. The Equivalent Weight of a Metal.	1
6	4. Preparation and Properties of Hydrogen and Reaction Rates.	1
	5. Acid, Base, or Salt?	1
	6. Diffusion of Gases.	1
	1. Boyle's Law and Graham's Law of Diffusion.	1
	2. Makeup Labs and Help Sessions.	1
7	3. Unknown Equivalent Weight.	1
	4. Relative Activities of Some of the Metals.	1
	5. Common Chemical Reactions.	1
	6. Hydrogen and its Properties.	1
	1. Molecular Weight of Carbon Dioxide.	1
	2. Atomic Weight, Specific Heat, and Equivalent Weight.	1
	3. The Packing of Atoms and Ions in a Crystal.	1
8	4. Water of Hydration of $BaCl_2$, Including Option or Unknown.	1
	5. Common Chemical Reactions.	1
	6. The Formula of Tin Oxide.	1
	1. Vapor Pressure of a Liquid	1
	2. Freezing Point of a Solution.	3
9	3. Ionic and Covalent Compounds.	1
	4. A Study of Hydrates, Per Cent Water of Hydration.	1
	5. Solubility Curve of NaCl.	1
	6. Anhydrides, Acid and Base, Supersaturated Solutions.	1
	1. Molecular Weight from Freezing Point Depression.	1
	2. Pure Substances and Mixtures, Melting Points.	1
	3. Preparation of Pure Substances.	3
10	4. Strong Acid-Base Titration.	1
	5. Titration of Vinegar (Unknown).	1

TABLE 46. (Continued)

Assignment	Title of Experiments	Periods in Weeks Devoted to Experiment
	6. Determination of Weight of Hydrogen and Equivalent Weight of Magnesium.	1
11	1. Group I - Known and Unknown.	1
	2. Radioactivity.	1
	3. Determination of the Forms of a Compound.	1
	4. Getting Substances to Dissolve, Acid and Bases, Conductivity of Solutions and Completion Reactions.	1
	5. The Effect of Temperature Changes on the Volume of a Gas at STP.	1
12	1. Titration of Vinegar, Hydrolysis, Electrolytes.	1
	2. Preliminary Qualitative Analysis and Unknown.	2
	3. Flame Tests and Group IV.	1
	4. Titration.	2
	5. Chemistry of Compounds of Nitrogen.	1
	6. Titration Experiment.	1
13	1. Titration of Acids and Bases.	1
	2. Organic Models.	1
	3. Test for Halides, Study Properties of Iodine and Chlorine.	1
	4. Anions - Preparation.	1
	5. The Seven-Bottle Experiment-*J. Chem. Educ.*	1
	6. Group II Anions.	2
14	1. Qualitative Analysis "Known."	1
	2. Properties of Sulfuric Acid.	1
	3. Preparation of a Salt.	1
	4. Organic Chemistry.	1
	5. Group I Anions.	2
	6. Group II Anions.	1
15	1. Qualitative Analysis "Unknowns."	1
	2. Flame Tests.	1
	3. Chemical Equilibrium and Reaction Rates.	1
	4. Building Structural Models of Organic Compounds.	1
	5. General Anion Unknown.	1
	6. Oxidation and Reduction.	1

TABLE 46. (Continued)

Assignment	Title of Experiments	Periods in Weeks Devoted to Experiment
16	1. Unknowns Equivalent Weight of a Solid Acid	1
	2. Semimicro Qualitative Analysis.	15 weeks
17	1. Oxidation and Reduction.	2 weeks
	2. Solubility and Rate of Solution.	2
18	1. Titration Involving Oxidizing and Reducing Agents.	2
	2. Solubility of NaCl in Water.	1
19	1. Production of an Electric Current by Means of Oxidation-Reduction Reaction.	1
	2. The Preparation and Coagulation of Colloids.	1
20	1. pH Meter and Indicator.	1
	2. The Organic Acid Content of Commercial Vinegar.	1
21	1. Unknown-pH Meter and Indicator	1
	2. The Ammonia Content of "Household Ammonia."	1
22	1. Reversible Reactions and Equilibrium.	2
	2. Chemical Analysis.	1
23	1. Ionization Constant of a Weak Acid.	1
	2. Paper Chromatographic Analysis.	1
24	1. Equilibria - Ions of Water, pH, Hydrolysis.	1
	2. The Qualitative Analysis of Baking Powder.	1
25	1. Solubility Product of a Slightly Soluble Salt.	1
	2. Alcohol Fermentation.	1
26	1. Some Elementary Experiments in Organic Chemistry.	1
	2. Removal of Stains from Fabrics.	1

the amount of time devoted to a given topic is probably related to the textbook author's special interest or to the instructor's personal preference. To teach all the facts of chemistry is an impossibility; however, a careful selection of topics with a conceptual scheme illustrating the processes of chemistry would add structure to the introductory college chemistry course.

CHAPTER IX

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The problem is restated here in the form of a question which is answered by the presentation of a summary of the findings assembled from the different parts of the completed questionnaires received from the accredited colleges and universities teaching introductory college chemistry. What are the present objectives, teaching methods, and materials used in teaching the introductory course in college chemistry in selected accredited colleges and universities in the continental United States?

The data from the survey support the following conclusions:

(1) The general objectives and aims of the introductory college chemistry course are: (a) to develop the ability to do critical thinking, (b) to make the students familiar with the facts, principles, and concepts of chemistry, (c) to help the student understand the nature of matter and its transformation, (d) to develop the ability to handle quantitative problems, (e) to develop intellectual honesty rather than foster the search for the "right answer," (f) to teach students to be precise in observation and expression. (Chapter V).

(2) A great variation in the titles as well as in the description of the introductory college chemistry course was evident; however, the term "General Chemistry" prevails as the choice course name. (Chapter IV).

(3) The survey findings reveal opposite points of view concerning whether to require a prerequisite for introductory college chemistry and with respect to the choice of prerequisite. This diversity revealed a listing of thirty-five course prerequisites with 39 per cent of all courses offered requiring no prerequisite. (Chapter IV).

(4) Credit in the different introductory chemistry courses ranged from two to twelve semester hours credit per year, while the average number of semester hours per course in all institutions surveyed was 7.29. The average number of courses offered per institution was 1.6 and the mean semester hours credit reported from the total number of semester hours offered in all introductory chemistry courses, i.e., all courses, per year was 11.9. The mean semester hour average for the different course offerings per year per university was 13.8; for liberal arts colleges was 10.2; for junior colleges was 11.2; and for specialized institutions was 12.0. (Chapter IV).

(5) The average number of college professors per university was less than six; less than three per liberal arts college and junior colleges; and four for each specialized institution. The fact that 89 per cent of the universities, 76 per cent of liberal arts colleges, and 18 per cent of junior colleges and 52 per cent of specialized institution professors have earned doctoral degrees in chemistry was encouraging, but all classifications of institutions are in need of more professors with earned doctorates. This was especially at the junior college level. (Chapter IV).

(6) College professors need more student assistants as evidenced by an approximate average of fifteen, five, three, and five student assistants per college for universities, liberal arts colleges, junior colleges,

and specialized institutions, respectively. The quality of help was probably less than desired since 31 per cent of the student assistants had no college degree, and 49 per cent had only earned a bachelor degree. (Chapter IV).

(7) The general practice of college professors during the past two years was to change the textbook and laboratory exercises, but to adhere to the same course outline, as revealed by an 82 per cent response to statements regarding change. (Chapter V).

(8) Fifty-nine per cent of the 212 institutions paid no attention to the high school chemistry background of the student, and the practice was to place all students in the same first-year college chemistry course. (Chapter IV).

(9) The consensus of a majority of the professors was that a course be offered in chemical properties with descriptive parts of the course used both to illustrate the principles and to show how they are derived. (Chapter IV).

(10) That 56 per cent of the participating college professors indicated the use of a combination of staff prepared and commercially prepared laboratory manual and textbook materials shows dissatisfaction with the present introductory college chemistry course content, especially the laboratory phase. (Chapter V).

(11) The low percentage use of equipment other than the single pan balance, the spectrophotometer, and the pH meter, showed that introductory college chemistry professors were not utilizing the modern teaching aids as suggested by the Advisory Council on College Chemistry. (Chapter V).

(12) The primary teaching method favored, other than lecture, was regular problem assignments. (Chapter V).

(13) University professors make more use of conference quizzes, and the junior colleges offer more self-assistance to students than do other categories of institutions. (Chapter V).

(14) Chemistry professors, in general, did not state course objectives. The participants from all institutions rejected the practice of stating course objectives and the ensuing preparation of methods of evaluating whether those objectives had been achieved, as revealed by a 42 per cent and a 19 per cent response to statements requesting the use of these educational endeavors. (Chapter V).

(15) The large proportion of the respondents regard the development of critical thinking, familiarity with the facts and principles of chemistry, and the development of the ability to handle quantitative problems as three of the five most important outcomes for the science major, yet the survey findings indicated rather clearly that there seems to be no objective way to determine whether an introductory course was successful. The more popular methods used to evaluate the success of the introductory college chemistry course were subjective observations, special examinations,[217] and discussion involving the entire chemistry faculty. Since the most typical course evaluation was subjective evaluation questions are raised with respect to how one knows when the common objectives of an introductory college chemistry course are achieved. (Chapter V).

(16) Although textbook changes were frequently made (see number 7 above), the previously stated course objectives have been changed very

---

[217]See p. 173, footnote d, for definition of special examinations.

little, as shown by a 64 per cent negative reply to a statement requesting an indication of a substantial change in course objectives, when an older course was replaced by a new course. (Chapter V).

(17) An examination of the laboratory experiences covered in the first six weeks of the laboratory phase of the general college chemistry course (see Table 46, Chapter VIII) reveals the existence of a diversity with respect to difficulty of content used to achieve the commonly agreed upon objectives of general college chemistry (see Table 32). The titles of the laboratory experiments in Table 46 represent a tremendous range of activities. These laboratory activities range from purely mechanical manipulations such as glass working techniques and gas burner operations to a highly sophisticated degree of abstract thinking experiences related to such topics as gas laws and the determination of molecular weights. Since laboratory experiences listed in Table 46 show a great diversity with respect to difficulty of content, serious questions need to be raised regarding the belief of participants in common objectives and the suitability of the content selected to achieve those objectives. What kinds of laboratory experiences are related to the development of critical thinking, i.e., the development of the rational powers? How is it possible to correlate a common set of objectives with a wide diversity of laboratory experiences and belief that accepted educational goals can be attained? (Chapter VIII).

(18) College chemistry professors either rejected and/or do not have time to prepare a course outline or syllabus. (Chapter V).

(19) Some colleges and universities are providing a variety of methods to challenge superior or talented students. These methods in-

clude (1) honors courses, (2) independent study, (3) advanced placement, (4) conference study, and (5) proficiency examination. (Chapter V).

(20) The professors listed twenty-six various reasons for changing the introductory college chemistry course. The foremost change factors mentioned were: (a) theories of chemistry are constantly changing, (b) more equipment and modern equipment are available for laboratory and instructional use, (c) advent of general college chemistry textbooks with a change in emphasis, and (d) large number of students beginning the study of first-year college chemistry are better prepared in terms of high school chemistry and mathematics. These accepted reasons for course change contradict the actions of college professors with respect to student placement (see item 8 above).

(21) The survey participants reaction to a list of factors which writers in the literature survey believed to be responsible for reducing student interest in freshman chemistry suggested that chemistry educators need to review their pedagogical practices. The factor receiving more checks for being responsible for reduction of student interest was, "topics are unrelated to student interest." The result of this review could be the development of some methods and techniques to help increase student interest in introductory college chemistry. (Chapter VII).

(22) The combination of findings related to factors which college professors believe to reduce student interest in freshman college chemistry and the suggestions directed at the goal of improving teaching suggest a needed revolution in attitudes of professors and methods of teaching. The participants favored a change in the methods of educating college teachers of chemistry even to the point of educating those people already

engaged in the teaching of first-year college chemistry. The need to teach introductory college chemistry as a process was indicated by an 85 per cent approval of all professors. (see Table 42, Chapter VII).

Recommendations

The investigator is of the opinion that some of the controversy in introductory college chemistry could possibly be resolved by some national organization sponsoring a curriculum study and writing conference similar to the Biological Science Study Committee (BSCS). The findings of this survey, the publications of the Advisory Council on College Chemistry, the Systems approach (see Appendix F), and the Hammond Curriculum might serve as guideline to the synthesis of some new chemistry innovations in first-year college chemistry. The investigator suggests a minimum of three courses of varying difficulty and goals--one for the general education major, one for the physical science major, and one for the biological science major; still another could be designed for the talented student. (There is some doubt that three courses could fit the diverse needs of the different institutions but three such courses would represent an improvement on currently available course offerings. Another problem would be found in selecting an approach to teaching the course which would satisfy a large number of professors). Specific attention should be directed to the learning of chemistry concepts and the development of a commonly agreed upon sequential arrangement of topics. The selection of course topics and the sequential arrangement of topics in a logical manner merits the attention of educators who understand learning and concept development. Behavioral objectives must be stated and teaching methodology which will stimulate student interest must be an integral part of each course. A writing conference could utilize the experiences of the numerous and successful teachers of general college chemistry and science educators. Trial centers should be established to allow each separate course to be tested by several college and university chemistry professors and science educators. When the testing period is completed, the experiences and writing talent of the authors of first-year college chemistry textbooks and laboratory manuals could be utilized in the preparation of commercial editions.

Methods to evaluate student progress and determine the worth of a given course must be designed, tested, and retested. The investigator believes that these courses (when designed, developed, and tested) will challenge the varying abilities of a divergent student population. These courses should also be commensurate with an individual student's academic preparation and, where possible, should correlate with his vocational plans. Special interest topics should be written to supplement these courses and challenge students.

Suggested Research

The survey returns with respect to course outlines and syllabi, and laboratory experiments including the educational value of pre-laboratory sessions, were insufficient to discern a trend. The low response of information concerning these topics when combined with the low percentage response to the request for titles of the textbooks and laboratory manuals (see Chapter VIII) suggest that additional research is needed for a complete description of the classroom and laboratory practices in general chemistry. The data in Chapter VIII also reflect the need of a study to determine the nature of the one-or-two hour sessions which are being devoted to problem sessions and/or problem discussions. How much time is devoted to problem sessions and what is the nature of these problem assignments?

A study is needed to determine how the professors of first-year college chemistry are being educated; such a study would have the objective of formulating guide lines for the education of future college chemistry teachers. How much does a college chemistry teacher know about learning and concept development? The low percentage use of objective methods for evaluating the worth of the introductory college chemistry course also suggest the need for research in course evaluation.

BIBLIOGRAPHY

A SELECTED BIBLIOGRAPHY

Books and Bulletins

Accredited Institutions of Higher Education. Washington, D. C.: American Council on Education, September, 1967.

Caldwell, Otis W. and Committee. Report of the Subcommittee on the Teaching of Science, Bulletin No. 26. Washington: U. S. Bureau of Education, 1920, pp. 12-13.

Cardinal Principles of Secondary Education. Bulletin No. 35. Washington: Department of Interior, Bureau of Education, 1918.

Carhart and Chote, in Woodburn and Obourn. Teaching the Pursuit of Science. New York: The Macmillan Company, 1965, p. 1962.

Dixon, Wilfrid J. and Massey, Frank J. Introduction to Statistical Analysis. New York: McGraw Hill Book Company, Inc., 1951, pp. 290-294.

Dugdale, Kathleen. A Manual of Form for Theses and Term Reports. Third Revision. Bloomington, Indiana: Dugdale, 1967.

Dugdale, Kathleen. A Manual on Writing Research. Bloomington, Indiana: Dugdale, 1967.

Educational Policies Commission. The Central Purpose of American Education. Washington, D. C.: National Education Association, 1962, p. 12.

Eliot and Storer, in Woodburn and Obourn. Teaching the Pursuit of Science. New York: The Macmillan Company, 1965, p. 196.

Frank, J. O. The Teaching of High School Chemistry. Oshkosh, Wisconsin: J. O. Franks and Sons, 1932, p. 8.

Haenisch, Edward L., ed. Modern Teaching Aids for College Chemistry. Los Angeles, California: Advisory Council on College Chemistry, 1966, pp. 1-7.

Haenisch, Edward L., ed. The Content of Introductory College Chemistry. Wabash, Indiana: Advisory Council on College Chemistry, December, 1964.

Hume, David N., Experimental Curricula in Chemistry. Wabash College, Indiana: Advisory Council on College Chemistry, October, 1963.

Neidig, H. A. and Kieffer, William F., Modern Experiments in Introductory College Chemistry. Easton, Pennsylvania: Journal of Chemical Education, 1967, Foreword.

Renner, John W. and Ragan, William B. Teaching Science in the Elementary School. New York: Harper and Row, 1968, p. 163.

Rudolph, Frederick. The American College and University. New York: Vintage Books, 1962, pp. 222, 223, 227, 229-231.

Turabian, Kate L. A Manual for Writers. Third edition, revised. Chicago: The University of Chicago Press, 1967.

United State Department of Health, Education, and Welfare. Opening Fall Enrollment in Higher Education, 1966. Washington, D.C.: United States Printing Office, 1967.

Woodburn, John and Obourn, Ellsworth S. Teaching the Pursuit of Science. New York: Macmillan Company, 1965.

Periodicals

Adams, C. S. "The Importance of Laboratory Work in General Chemistry at the College Level," Journal of Chemical Education, 20, (1943), pp. 266-270.

"AC_3 May Expand Its Scope to Include Action with Advise," Chemical and Engineering News, 45, November 13, 1967, p. 40.

"AC_3 Zeros In On Chemical Education," Chemical and Engineering News, 44, August 1, 1966, pp. 40-41.

"Advisory Council on Chemistry Set Up," Chemical and Engineering News, 41, January 14, 1963, pp. 43-44.

Alyea, Herbert N. "The Function of General Chemistry," Journal of Chemical Education, 18, (1941), p. 310.

Arenson, Saul B. "Demonstration Versus Laboratory Once Again," Journal of Chemical Education, 15, (1938), p. 592.

Babor, Joseph A. "The Sequence of Topics in General Chemistry," Journal of Chemical Education, 25, (1948), pp. 263-264.

Bakker, G. R., et al. "The Earlham Chemistry Curriculum," Journal of Chemical Education, 41, (1964), p. 135.

Barrow, Gordon M. "Dull Approach Leads to Fewer Graduates," Chemical Engineering News, 46, June 10, 1968, p. 65.

"Big Classes Create Big Problems," Chemical and Engineering News, 41, October 28, 1963, pp. 48-50.

Blick, David J. "The Purpose and Character of Laboratory Instruction," Journal of Chemical Education, 32, (1955), pp. 264-266.

Calvetti, John E. "The Perennial Problem of Course Content in a Growing Science," Journal of Chemical Education, 20, (1943), pp. 271-273.

Carnell, Paul H. "Independent Study Programs for Freshmen," Journal of Chemical Education, 35, (1958), pp. 250-253.

Clapp, Leallyn B. "The Brown Experiment in Chemical Education," Journal of Chemical Education, 35, (1958), p. 170.

"Chemical Publishers Push Teaching Aids," Chemical and Engineering News, 46, August 19, 1968, pp. 32-35.

Cochran, William G. Sampling Techniques. New York: John Wiley and Sons, Inc., 1953, p. 88.

Cooke, R. L. "Demonstration Versus Laboratory Once Again," Journal of Chemical Education, 15, (1938), p. 592.

Cornell, F. G. "A Stratified Random Sample of a Small Finite Population," Journal of American Statistical Association, 42, (1947), p. 523.

Cornog, Jacob and Colbert, J. C. "What We Teach Our Freshmen in Chemistry," Journal of Chemical Education, 1, (1924), pp. 5-12.

Coulson, Francis C. "Educational Aims in Teaching Elementary Chemistry," Journal of Chemical Education, 6, (1929), p. 1120.

Crossley, M. L. "Training for the Profession of Chemistry," Journal of Chemical Education, 2, (1925), p. 667.

Currier, Arnold J. "Trends in Chemical Education," Journal of Chemical Education, 37, (1955), pp. 286-289.

Davidson, Norman. "Theoretical Chemistry and Descriptive Chemistry in the General Chemistry Course," Journal of Chemical Education, 27, (1950) pp. 445-447.

Deming, Horace G. "Guinea Pigs in the Classroom," Journal of Chemical Education, 25, (1948), pp. 445-449.

Desch, C. H. "The Discipline of Chemistry," Nature, 116, (1925), pp. 504-505.

Dodson, B C and Castleberry, George. "A Comparison of the One-Year High School and Freshman College General Chemistry Textbooks," An unpublished survey, University of Oklahoma, Norman, 1966.

"Editorially Speaking," Journal of Chemical Education, 41, (1964), p. 115.

Elving, Phillip J. "The Curriculum in Chemistry," Journal of Chemical Education, 29, (1952), p. 219.

Engelhardt, Max D. "A Psychological Basis for Objectives," Journal of Chemical Education, 4, (1927), p. 364.

"Flexibility Urged in Graduate Support," Chemical and Engineering News, 41, November 25, 1963, pp. 42-44.

Fooks, Joyce Lane, editor. "Advisory Council on College Chemistry," The College Commissions, July, 1967, p. 8.

Fuller, Edward C. "Scarce MultiD Courses Gain Ground," Chemical and Engineering News, 45, September 18, 1967, pp. 66-67.

Garrett, A. B., et al. "The College Chemistry Course for Non-Science Majors," Journal of Chemical Education, 38, (1961), pp. 253-254.

Garrett, Henry E. Statistics in Psychology and Education. Fourth Edition. New York: Longmans, Green and Company, 1953, p. 173.

Gordon, N. E., et al. "Correlation of High School and College Chemistry," Journal of Chemical Education, 4, (1927), pp. 640-656.

Haenisch, Edward L. and Salter, Lewis S. "Integrated Introductory Course in Physics and Chemistry," Journal of Chemical Education, 35, (1958), pp. 246-247.

Hammond, George. "Proposal Revamps Chemistry Curriculum," Chemical and Engineering News, 44, November 14, 1966, p. 45.

Hendricks, B. Clifford. "How We Teach Freshman Chemistry," Journal of Chemical Education, 2, (1925), pp. 1187-91.

Horton, R. E. "Does the Laboratory Belong?" Journal of Chemical Education, 5, (1928), pp. 1432-1443.

Hume, David N. "Teachers Try to Unify Laboratory Courses," Chemical and Engineering News, 45, November 20, 1967, pp. 53-54.

Kendall, J. General Chemistry. New York: The Century Company, 1927, p. vi.

Kieffer, William F. "The Place of the Scientific Method in the First Course in Chemistry," Journal of Chemical Education, 28, (1951), p. 300.

King, L. Carroll. "A Special Course for Superior Students," Journal of Chemical Education, 35, (1958), p. 250.

King, L. Carroll. "Modern Texts are Needed to Upgrade College Chemistry Courses; Freshmen Often Ready for Quantum Chemistry, Thermodynamics," Chemical and Engineering News, 42, February 14, 1964, pp. 42-44.

King, L. Carroll in "Recent Trends in Undergraduate Chemistry Curricula," Journal of Chemical Education, 41, (1964), p. 126.

Kokes, B. J. "The Present Chemistry Curriculum at the John Hopkins University," Journal of Chemical Education, 41, (1964), p. 131.

McKain, Nelson, Jr. "Rigor or Breadth for Freshmen," Chemical and Engineering News, 42, March 23, 1964, p. 4.

Meloy, Carl R. "Some Trends in the Teaching of General Chemistry," Journal of Chemical Education, 31, (1954), p. 424.

Merwin, B. W. "Development of the Curriculum in College Chemistry," Journal of Chemical Education, 12, (1935), p. 543.

Montaque, Earl T. and Butts, David P. "Behavioral Objectives," The Science Teacher, 35, March, 1968, pp. 33-35.

Morgan, William C. "Symposium: What are Our Objectives in Teaching Chemistry?" Journal of Chemical Education, 2, (1925), pp. 971-975.

Nash, Leonard K. "Boundary Conditions," Journal of Chemical Education, 41, (1964), pp. 445-449.

Nechamkin, H. J. "The Course Content of General Chemistry," Journal of Chemical Education, 38, (1961), p. 255.

Neyman, J. "On the Two Different Aspects of the Representative Method," Journal of the Royal Statistical Society, 97, (1934), pp. 558-606.

Noyes, W. A., Jr. "Training the Chemist--A Critical Survey," Chemistry Bulletin, 12, (1925), pp. 67-68.

Parker, Garland G. "Statistics of Attendance in American Universities and Colleges, 1966-67," School and Society, January 7, 1967.

Pickets, John A. "A Laboratory Exercise Emphasizing Deductive Reasoning," Journal of Chemical Education, 37, (1960), p. 311.

"Preliminary Report of a Minimum First Year College Course in Chemistry," Journal of Chemical Education, 1, (1925), pp. 93-95.

"Proposal Revamps Chemistry Curriculum," Chemical and Engineering News, 44, November 14, 1966, p. 48.

Scott, Arthur F. "Retreading the Chemistry Teacher," Journal of Chemical Education, 37, (1960), pp. 442-445.

Sheerer, Leonard F., in Adams. "The Importance of Laboratory Work in General Chemistry at the College Level," Journal of Chemical Education, 20, (1943), pp. 267-268.

Shotton, J. A. "General Chemistry Workshop," Journal of Chemical Education, 37, (1960), pp. 442-45.

Smith, E. W. "Improvement of the Individual Laboratory Exercise in Chemistry," Journal of Chemical Education, 6, (1929), pp. 1130-1135.

Smith, Otto M. "Accepted Objectives in the Teaching of General College Chemistry," Journal of Chemical Education, 12, (1935), p. 182

Stinson, Frank E. "Aims and Objectives for an Initial Course in College Chemistry Designed for the Non-Science Major," Dissertation Abstracts, 20, (1959), p. 59.

Strong, Laurence E. and Benfey, O. Theodore. "Chemical Concepts and the Chemistry Curriculum," Journal of Chemical Education, 38, (1961), p. 251.

Strong, Laurence E. "College Chemistry--The Road to Nonsense or Science," Chemical and Engineering News, 43, February 22, 1965, p. 128.

Summerbell, Robert K. "The Excitement of Experiment," Journal of Chemical Education, 41, (1964), p. 126.

Swift, E. H. "Freshman Chemistry Laboratory at the California Institute of Technology," Journal of Chemical Education, 35, (1958), pp. 248-250, and p. 44.

Symposium, "Recent Trends in Undergraduate Chemistry Curricula," Journal of Chemical Education, 41, (1964), pp. 126-147.

Tamres, Milton and Bailar, John C., Jr. "The First Course in General Chemistry," Journal of Chemical Education, 29, (1952), p. 217.

Taylor, L. W., Chairman, et al. "Chemistry Instruction for Purposes of General Education," Journal of Chemical Education, 18, (1941), p. 11.

"Teachers Try to Unify Laboratory Courses," Chemical and Engineering News, 45, November 20, 1967, pp. 53-54.

"Teachers Devise Three Year Lab Programs," Chemical and Engineering News, 45, August 28, 1967, p. 74.

Walter, Robert I. "The Changing Curriculum in Chemistry: Some Contemporary Developments," Journal of Chemical Education, 42, (1965), pp. 524-527.

Westheimer, Frank H. "Chemistry: Opportunities and Needs," Chemical and Engineering News, 43, November 29, 1965, p. 93.

Wiberely, Stephen E. and Richtol, Herbert H. "A New Freshman Chemistry Program," Journal of Chemical Education, 41, (1964), p. 147.

Wildman, Ernest A. "The Need of Modernizing the General Chemistry Courses," Journal of Chemical Education, 11, (1934), p. 11.

Williford, Bennett R. "The Undergraduate Training of Chemistry Majors," Journal of Chemical Education, 38, (1961), pp. 251-253.

Yalman, Richard G. "Chemistry in Liberal Arts Colleges," Journal of Chemical Education, 41, (1964), p. 145.

Young, Jay A. "The Content of the First Course in College Chemistry," Journal of Chemical Education, 41, (1964), pp. 477-478.

Young, Jay A. "The Educational Use of Data--Challenge in the Laboratory," Journal of Chemical Education, 41, pp. 120-123.

APPENDIX

APPENDIX A

STATISTICAL CALCULATIONS

STATISTICAL CALCULATIONS

The following formulas were adopted from William G. Cochran, <u>Sampling Technique</u>. New York: John Wiley and Sons, Inc., 1953, pages 74, 82, 88, and 89.

<u>Theorem</u>: In stratified random sampling, the variance of the estimated mean $\bar{y}_{st}$ is smallest, for a fixed total size of sample, if the sample is allocated with n_h proportional to $N_h S_h$.

<u>Proof</u>: The problem is to minimize

$$V(\bar{y}_{st}) = \frac{1}{N^2} \sum_{h=1}^{L} N_h(N_h - n_h) \frac{S_h^2}{n_h}$$

subject to the restriction

$$n_1 + n_2 + \dots + n_L = n$$

The n_h and the Lagrange multiplier λ are selected so as to minimize

$$V(\bar{y}_{st}) + \lambda\ (n_1 + n_2 + \dots + n_L - n)$$

$$= \frac{1}{N^2} \qquad \frac{N_h^2}{n_h} - N_h \qquad S_h^2 + \lambda\ (n_1 + n_2 + \dots + n_L - n)$$

Differentiating with respect to n_h, the following equation is obtained

$$- \frac{N_h^2}{N^2} \quad \frac{S_h^2}{n_h^2} + \lambda = 0 \qquad (1)$$

This gives

$$n_h = \frac{N_h S_h}{N\sqrt{\lambda}}, \text{ or } n_h \propto N_h S_h \qquad (2)$$

To find the actual value of n_h, add (1) over the strata. Thus

$$\Sigma\, n_h = n = \frac{N_h S_h}{N\sqrt{\lambda}} \qquad (3)$$

Substitution for $\sqrt{\lambda}$ into (2) gives

$$n_h = n\ \frac{N_h S_h}{\Sigma\ N_h S_h} \qquad (4)$$

This result states that the sample size in a stratum should be proportional to the product of the size of the stratum and the standard deviation of the stratum, or, in other words, that the sampling fraction n_h/N_h should be proportional to the standard deviation. Other things being equal, a larger sample is needed in a variable stratum.

An expression for the minimum variance is obtained by substituting the values of n_h given by (4) into the general formula for $V(\bar{y}_{st})$. This gives

$$V \min (\bar{Y}_{st}) = \frac{1}{N^2}\ \frac{(\Sigma\ N_h S_h)^2}{n} - \frac{1}{N^2}\ \Sigma\ N_h\ S_h^2 \qquad (5)$$

If _V_ is the desired variance for the estimated population _total_, the principal formula becomes as follows:

Presumed optimum (for fixed n):

$$n = \frac{(\ \Sigma\ \ N_h S_h)^2}{V + \Sigma\ \ N_h S_h^2} \qquad (6)$$

APPENDIX B

QUESTIONNAIRE

SOUTHERN STATE COLLEGE

MAGNOLIA, ARKANSAS

Dear Colleague:

You are invited to assist in a survey of the objectives, teaching methods, and materials used in the teaching of the introductory course in college chemistry. This research is supported by the United States Department of Health, Education, and Welfare, proposal number 7G018.

The purpose of the survey is to determine using a wide scale sample what objectives, teaching methods, and materials are used in the introductory chemistry course in accredited colleges and universities. This questionnaire calls for facts concerning the teaching of introductory college chemistry in your institution. Completion of this questionnaire may appear to be quite a task, but for the most part it is a check list. This questionnaire also refers to courses which give credit under the title, "Chemistry." The questionnaire is not particularly concerned with those courses designed for non-science majors or for physical science credit and the like that do not meet prerequisite requirements for further courses in your curriculum. If you do not teach in the introductory college chemistry course, will you kindly pass this questionnaire to the person who does.

You are no doubt interested in learning what is being taught in the introductory college chemistry courses. A copy of the abstract of the study will be sent to you for your most gracious assistance.

A stamped, self-addressed envelope is enclosed for your convenience. Please return the questionnaire as soon as possible. Thank you for your cooperation in this matter.

Cordially yours,

B C Dodson

B. C. Dodson
Head of Chemistry Department

BCD/bp
Encl.

QUESTIONNAIRE

PART I

INFORMATION ON INTRODUCTORY COLLEGE CHEMISTRY COURSES

1. Please list the titles of the introductory college chemistry courses offered under the title "Chemistry" in your institution or attach pages from the college catalog listing these. (Omit non-science chemistry courses or pre-nursing courses and the like that do not meet prerequisite requirements for further coures in your chemistry curriculum.)

Course Number	Course Title	Course Enrollment Per Year	Pre-requisite(s)	Credit (Semester Hrs.)

2. Approximately what percent of the students in these courses have had some previous chemistry? (Please give approximate percentages, not numbers.)

_____ have had no chemistry

_____ have had a traditional high school chemistry course

_____ have had Chems or CBA

3. Approximately what percent of the students in these courses eventually major in chemistry? (Please give percent, not numbers.) ______________________

4. Faculty Personnel:

	Field of Highest Degree (Chem., Educ., etc.)	Highest Degree B.S. M. S. Ph.D.
Name of Professor in charge of introductory college chemistry: ______________	______________	( ) ( ) ( )
Number of other professors that teach lecture or laboratory sections of introductory chem.: (Place number in bracket with each degree.)		
______________	______________	( ) ( ) ( )
______________	______________	( ) ( ) ( )

Number of student assistants: _____ Highest Degrees of these student assistants: (Place number in bracket with each degree.)

No Degree ( )

( ) ( ) ( )

Responsibility: ( ) lecture ( ) laboratory ( ) other (specify) ______________

5. Check the classification of your college or university:

( ) a. Junior College

( ) b. College of Liberal Arts

( ) c. Specialized Institution

( ) d. University

CLASSIFICATION SCHEME: Junior College is an institution offering a two year program of study beyond the level of the secondary school, and this college work can be transferred to a baccalaureate degree. College of Liberal Arts refers to those institutions in which the principal emphasis is placed on the program of general undergraduate education. Specialized Institution is the category which includes schools that offer degree programs directed toward one or more fields of specialization that are not attached to a liberal arts college or university. They are principally schools of technology, teacher training, theological schools, etc. University refers to those institutions in which there is considerable stress on graduate instruction, which confers advanced degrees in schools that are not exclusively technological.

6. Is your chemistry department accredited by the American Chemical Society?

( ) Yes

( ) No

7. What is the typical course(s) that you offer students entering the introductory chemistry course?
(Check all statements that pertain; respond only to those statements that apply to your institution.)

( ) a. No distinction as to chemistry background. All students take same course.
( ) b. Course is designed in such a way that the better prepared student can complete the equivalent of one year course in one semester.
( ) c. Place all students together but compensate for the student who has had no prior study in chemistry by using some of the early laboratory periods as drill sessions to give students experience in momenclature, elementary facts of atomic theory, and equation writing. Are these sessions extra _____ or regular __ __?
( ) d. Selected students are given a brief review and then placed in an honors section by examination.
( ) e. Offer several introductory chemistry courses of varying difficulty; how many such courses ______?
( ) f. Give a sufficiently different course in the laboratory such that no student feels he is repeating the course. Try to eliminate trivia and introduce advanced and non-traditional topics.
( ) g. Other (Specify) ____

____

8. Complete this section only if you teach an "honors" course. If you have no honors course check here ( ).

   A. What description best fits the nature of the course? (Check only one)
      ( ) 1. One which omits descriptive inorganic and schematic scheme of analysis.
      ( ) 2. A one semester course followed by thermodynamics.
      ( ) 3. A course in chemical principles with descriptive chemistry.
      ( ) 4. A course comprising largely organic chemistry.
      ( ) 5. A combined chemistry-physics course.
      ( ) 6. A course in crystal structure.
      ( ) 7. Other (Specify) ________________________________

   B. What methods are used for selecting the students? (Check all statements that pertain.)
      ( ) 1. Placement Examination
      ( ) 2. College Board Examination
      ( ) 3. Special Examinations (________________________)
      ( ) 4. High School Science Background
      ( ) 5. High School Record
      ( ) 6. American College Testing Program (ACTP)
      ( ) 7. American Chemical Society Examination
      ( ) 8. ACT Grade in Mathematics
      ( ) 9. High School Chemistry Grade
      ( ) 10. Other (Specify) ________________________________

      Rank the above methods in the importance attached to the selection of students by placing your choice of 1, 2, 3, 4, to the left of the checks.

   C. Which of these best describes the suitability of the "available" textbooks for this course or independent study? (Choose One)
      ( ) 1. Suitable textbooks and laboratory manuals are available.
      ( ) 2. None of the existing textbooks or laboratory manuals suit our purpose.
      ( ) 3. Other (Specify) ________________________________

9. In this investigation the majority of the currently available textbooks and laboratory manuals are considered as representing the "conventional" course. Please react to the following six statements about the conventional course. If you agree with the statement, encircle "A". If you disagree with the statement, encircle "D". If you are undecided about the statement, encircle "U".

   The "conventional" course in college chemistry:

1. is generally satisfactory for all students.	A	D	U
2. is more appropriate for students who major in chemistry than those who do not.	A	D	U
3. could be significantly modified for the superior student with a good high school background in science and mathematics by eliminating descriptive matter and introducing more advanced non-traditional topics.	A	D	U
4. needs new textbooks of varying difficulty but adhering to traditional topics stressing the products of chemistry	A	D	U
5. should be taught from textbooks of varying difficulty but utilizing the inquiry approach, i.e., stressing the processes of chemistry.	A	D	U

6. will continue because the time and cost are essential factors which have tended to retard the introduction of chemistry innovations analagous to C.B.A. and CHEM study at the introductory college level. A D U

10. Which of these best describes the laboratory manual or text that you use in the introductory college chemistry course? (check one)

( ) a. Only materials prepared by the chemistry staff.
( ) b. Only published material which is available commercially
( ) c. A combination of the above.
( ) d. Other (specify) ______

11. What type of pre-laboratory instruction do you give the introductory college chemistry students? (Please check all that apply.)

( ) a. Students are expected to have read directions.
( ) b. Students are assigned supplementary readings other than laboratory manual directions.
( ) c. A pre-laboratory drill assures that students have read directions.
( ) d. A pre-laboratory quiz assures that students have read directions.
( ) e. A pre-laboratory quiz assures that students have read supplementary readings.
( ) f. A pre-laboratory quiz assures that students have worked the drill.
( ) g. The experiment is demonstrated.
( ) h. Procedure is discussed.
( ) i. The theoretical basis of the experiment is discussed.
( ) j. Questions are answered.
( ) k. Special emphases and different points are elucidated.
( ) l. Other (please specify) ______

12. How do your introductory chemistry students handle experimental data? (Check one)
( ) a. Data are recorded in duplicate by use of carbon paper.
( ) b. Data are recorded on blank separate sheets.
( ) c. Data are recorded in blank notebooks.
( ) d. Data are recorded on special printed forms you provide separately.
( ) e. Other (specify) ______

13. What type of reporting do you expect from the introductory chemistry students? (Please check all that apply.)
( ) a. Fill in data and results on printed sheets.
( ) b. Students design their own report sheets.
( ) c. Full reports (essay form).
( ) d. Sample calculations only.
( ) e. Full calculations.
( ) f. Duplicate raw data sheets (carbon paper record).
( ) g. Supplementary questions are answered in the laboratory.
( ) h. Graphs from data in the laboratory.
( ) i. Other (Specify) ______

14. Do your introductory students perform special projects? ( ) yes ( ) no
If yes, approximately what percent of the laboratory course

15. Excluding the honors course or specialized course, how are you challenging the superior student who has successfully completed high school chemistry, and in addition, shows special talent? (Check all statements that pertain to your institution.)

A. No provisions made, because-
( ) 1. No interest.
( ) 2. Lack of student time.
( ) 3. Lack of professor time.
( ) 4. Lack of facilities.
( ) 5. Do not have, but are interested.
( ) 6. Other (Specify)____________________

B. Independent Study: (The student carries on a study of basic research under the direction of a faculty member and prepares a paper on his work in the manner of a journal article.) The nature of this independent study is a -
( ) 1. Special laboratory project.
( ) 2. Special problem in qualitative analysis.
( ) 3. Special problem selected by the individual student.
( ) 4. Special problem selected by the chemistry department.
( ) 5. Do not have, but are interested.
( ) 6. No interest.
( ) 7. Other (Specify) ____________________

C. Conference Study or Conference Sessions: (Informal meetings on a variety of topics-freshman presentation.)
( ) 1. Seminar.
( ) 2. Assist professors or graduate students in preparing papers to be presented at seminars.
( ) 3. Other (Specify) ____________________

D. Advanced Placement ( ). Describe ____________________

16. Answer parts (A) and (B): then complete this section only if your department has in the last two years revised its old course and/or added a new course.

A. Has your department added a new introductory chemistry course in the last two years?
( ) 1. Yes
( ) 2. No

B. Has your department made such changes as textbook change or revision and/or laboratory exercise changes or revision in the introductory chemistry course in the last two years?
( ) 1. Yes
( ) 2. No

C. If your answer to either 16-A or 16-B is Yes, please answer the following questions by encircling "Y" if your answer is Yes; encircle "N" if your answer is No; and encircle "U" if you are Uncertain.
1. Have the content and program of instruction been considerably modified but the framework of the old course retained? Y N U

2. Do you rely mainly upon a single textbook and laboratory manual in the new or revised course? Y N U
3. Are you using an outline or syllabus which was prepared especially for the new course? Y N U
4. Does the new course attempt to treat much of the traditional content such as the study of gases, liquids, solids, etc. as separate units? Y N U
5. Do you expect more reading outside the text in the new or revised course than in the old course? Y N U
6. Is the work in the new or revised course independent of collaboration with physicists? Y N U
7. In the new or revised course has your department prepared a list of independent studies or research requiring investigations which can be carried on by the individual student outside the classroom and/or laboratory? Y N U
8. Has your department prepared special tests or other means of evaluating student achievement of the distinctive aims for the new or revised course? Y N U
9. Does your new and/or revised course have a set of objectives which have been formally stated and to which all members teaching the course have access? Y N U
10. Do the objectives of the new and/or revised course differ substantially from the objectives of the older course? Y N U

17. Which of the following best represents your opinion of what the introductory course in college chemistry should be? (Choose only one.)

( ) 1. A course in chemical principles with descriptive chemistry serving only to illustrate these concepts.

( ) 2. A course based heavily on laboratory and classroom demonstration of a phenomenon.

( ) 3. An integrated course in physics, chemistry, and mathematics.

( ) 4. An inventory of factual materials and phenomenological formulas needed for advanced study.

( ) 5. Other (Specify) ____________________

PART II

OBJECTIVES AND AIMS OF THE INTRODUCTORY COLLEGE CHEMISTRY COURSE

Indicate by encircling the letter "A" those objectives which you believe to be very important; encircle "S" those objectives which you believe to have some importance; and encircle the letter "D" those which you believe are not at all important.

Which of the following do you believe to be the most significant aims and objectives which the study of introductory college chemistry should allow a student to achieve? (Respond to each statement)

1. Show the relationship of chemistry to other sciences.	A	S	D
2. Help the student to understand the nature of matter and its transformations.	A	S	D
3. Develop the ability to do critical thinking.	A	S	D
4. Make students familiar with the facts, principles, and concepts of chemistry.	A	S	D
5. Acquaint students with new findings of chemistry and to point out their applications to everyday life.	A	S	D
6. Help the student to discover whether he has an aptitude to work in pure or applied science.	A	S	D
7. Give students an idea of the importance and significance of chemistry in our national life.	A	S	D
8. Development of specific interests, habits, and abilities which should be contributed to by all courses in science.	A	S	D
9. Expand the interest of individual students by encouraging hobbies and outside activities which are related to chemistry.	A	S	D
10. Develop the ability to handle quantitative problems (as they are usually treated in chemistry textbooks.)	A	S	D
11. Stimulate the desire to read literature pertaining to beginning chemistry and other scientific work.	A	S	D
12. Teach students to be precise in observation and expression.	A	S	D
13. Involve a student in a scientific inquiry which combines theory and experiments in the solution of the problem.	A	S	D
14. Provide practice and reliable recording of data (the acquisition and ordering of data) and training in how to differentiate between relevant and irrevelant data.	A	S	D
15. Formulate, as well as answer, questions.	A	S	D
16. Develop intellectual honesty rather than foster the search for the "right" answers.	A	S	D
17. Train the student to analyze errors and to learn how to minimize them by making appropriate modifications in experimental procedure.	A	S	D
18. Train the student to recognize the limitations of a given experimental method and learn how such limitations may be overcome.	A	S	D
19. Provide the student direct experiences related to concepts expounded in the classroom.	A	S	D
20. Demonstrate the extension of human sensory perception by appropriate instruments.	A	S	D
21. Develop selected manipulatory skills involved in laboratory techniques.	A	S	D

22. To bring the student to the point where he can function in a scientific laboratory, or to enable him to understand the reason for the existence of laboratories and the basis of action carried out by those who work there. A S D

23. Obtain (efficiently) reliable data which can be applied to yield an answer to a meaningful question the investigator has proposed about the behavior of nature. A S D

24. Other (Specify) ________________________________

25. What five of the above statements (1-24) do you consider to be the most significant objectives of introductory chemistry? Rank these five choices in the most importance attached to course objectives by placing the number of the most important objectives in descending order from left to right: ________________________________

26. How do you evaluate the success of the introductory chemistry course in your institution? (Check all that apply)

( ) 1. Special examination.
( ) 2. Subjective observations.
( ) 3. By using a student-completed questionnaire.
( ) 4. Discussion involving the entire chemistry faculty.
( ) 5. No evaluation.
( ) 6. Other (Specify) ________________________________

Indicate a periodic or spasmodic evaluation by placing a "p" or an "s" at the end of the sentence of your choice.

PART III

SUPPLEMENTARY MATERIALS, EQUIPMENT, AND METHODOLOGY USED IN THE INTRODUCTORY COLLEGE CHEMISTRY COURSE

Place a check mark in the box located to the left of those supplements that you use to assist you in teaching the introductory college chemistry course. Place a check in column "A" if supplements are used in the classroom by instructor and a check in column "B" those supplements used outside the classroom by students.

	Supplementary Materials	A	B
( )	1. Study guidesprepared by the chemistry faculty.	____	____
( )	2. Student personal data inventories.	____	____
( )	3. File of previous given chemistry tests.	____	____
( )	4. Bibliography of reading materials for students	____	____
( )	5. Study Materials:		
	a. Articles	____	____
	b. Books	____	____
	c. Film Loops	____	____
	d. Programmed Materials	____	____
	e. Other (Specify) ______________	____	____
( )	6. Atomic and molecular models.	____	____
( )	7. Visual aids.	____	____
	a. Filmstrips	____	____
	b. Overhead projector	____	____
	c. Opaque projector	____	____
	d. 8 mm or 16 mm projector	____	____
	e. Closed circuit television	____	____
	f. Other (Specify) ______________	____	____
( )	8. Paperback books available in the college bookstore.	____	____
( )	9. Videotape.	____	____
( )	10. Computer assisted instruction.	____	____
( )	11. Other (Specify) ______________	____	____

		Equipment Use		
	Equipment	Demonstration	Student Experiments	Study of Design
( )	12. Direct reading balances.	( )	( )	( )
( )	13. Gas Chromatograph.	( )	( )	( )
( )	14. Infra-red spectrophotometer.	( )	( )	( )
( )	15. Bausch and Lomb Spectronic 20.	( )	( )	( )
( )	16. PH Meter	( )	( )	( )
( )	17. Conductivity bridge.	( )	( )	( )
( )	18. Polarimeter.	( )	( )	( )
( )	19. Geiger counter or scintillator.	( )	( )	( )
( )	20. Paperchromatography.	( )	( )	( )
( )	21. Other (Specify) ______________			

Outside Materials

( ) 22. Field trips, exploration trips, local industry, resource speakers (outside speakers.) Underscore those used.
( ) 23. Chemistry club and parties.
( ) 24. Other (Specify) ______________________________

Methodology and Techniques

( ) 25. Demonstrations (teacher and/or students).
( ) 26. Panel Discussions.
( ) 27. Team teaching and/or committee teaching.
( ) 28. Programmed instruction.
( ) 29. Review sessions and/or tutorial sessions.
( ) 30. Conference quizzes.
( ) 31. Series of quizzes, tests - objective and subjective.
( ) 32. Student conferences with faculty members.
( ) 33. Regular problem assignments.
( ) 34. Urge the students in class and out of class to use the library forother than textbook reading.
( ) 35. Require term papers on topics not adequately covered in textbooks or secondary sources.
( ) 36. Special topics and reports.
( ) 37. Student presentation of problems and solutions.
( ) 38. Assign research journal articles for reading.
( ) 39. Presenting the limited but useful aspects of "black box" instruments.
( ) 40. Let students plan, execute, and interpret experiments.
( ) 41. Using "open-ended" experiments.
( ) 42. Devise experiments so that original sources must be consulted.
( ) 43. Using some laboratory experiments which "stand on their own feet," i.e., experiments which are not dependent on materials discussed in the classroom. If not, why? ______________________________
( ) 44. Using simple "mock-up" rather than complex apparatus to concentrate the student's attention on ideas rather than manipulation.
( ) 45. Other (Specify) ______________________________

PART IV

FACTORS THAT REDUCE INTEREST IN THE INTRODUCTORY CHEMISTRY COURSE

What are the factors that tend to limit student interest in the introductory chemistry course?

( ) 1. Topics are unrelated to student interest.
( ) 2. Too much theory.
( ) 3. Not enough laboratory work.
( ) 4. Insufficient or inadequate laboratory equipment.
( ) 5. Lack of library facilities.
( ) 6. Not enough individual work.
( ) 7. Too much memory work.
( ) 8. Subject too formally presented.
( ) 9. Instructor teaching too many subjects or students.
( ) 10. Facts taught as ends (products) of science rather than a means (processes) of science.
( ) 11. Too much teacher dependence on textbook.
( ) 12. Too much telling - too teacher domination.
( ) 13. Failure of instructor to clarify a general principle.
( ) 14. Failure to use "practical tangibles" in place of "textbook tangibles."
( ) 15. Too little faculty time --too involved in research or other activities.
( ) 16. Poor instruction by graduate assistants.
( ) 17. Other (Specify) ______________________________

PART V

REASONS FOR CHANGING THE INTRODUCTORY COLLEGE CHEMISTRY COURSE

1. What do you consider as compelling reasons for considering course revision? (Check all statements that pertain.) Check here ( ) if you consider your present course satisfactory and no course revision is necessary.
   ( ) a. The availability of more equipment and more modern equipment for laboratory and instructional use.
   ( ) b. Impact of CBA, CHEMS, PSSC courses.
   ( ) c. The number of chemistry majors is diminishing.
   ( ) d. Theories of chemistry are constantly developing.
   ( ) e. Advent of general chemistry textbooks with a change in emphasis.
   ( ) f. Flood of new information appearing in the chemical literature.
   ( ) g. Large number of students beginning the study of introductory college chemistry and the fact that many of these students are better prepared in terms of high school chemistry and/or mathematics.
   ( ) h. Other (Specify) ______________________________

2. Rate these items as you believe they should be developed to improve the teaching of college chemistry at the introductory level. (Indicate by encircling "A" those things which you believe to be very important; encircle "S" those things which you believe to have some importance; and encircle "D" those things which you believe are not at all important.)

   A. The development of test-like instruments for discovering the particular needs and interests of students and the selection of contents and teaching procedures to meet those needs and interests. A S D

B. The preparation of tests designed to measure the achievement of students with respect to certain aims not now specifically tested such as understanding the processes or methods of chemistry as well as the content and the ability to do critical thinking. A S D

C. The retraining of those people already engaged in the teaching of the introductory college course in chemistry to meet the current trend in science teaching. A S D

D. A revolution in attitudes and methods of teaching (the search for fresh and flexible teaching techniques) and in the methods of educating college teachers of chemistry. A S D

E. A shift from the traditional emphasis of stressing the facts and products of the discipline of chemistry to the teaching of the processes of chemistry which will be valuable in all learning long after the facts are forgotten. A S D

F. Other (Specify) ______________________________

PART VI
ADDITIONAL INFORMATION

1. What other specific uses or additional information for which space and headings are not provided can you supply? Please feel free to add all you can. You may use the back of this page or attach a page. A syllabus of your introductory chemistry course or any other related material would be helpful to the study.

2. ______________________________
Name of person completing this questionnaire

( ) Professor
( ) Associate Professor
( ) Assistant Professor
( ) Instructor

Do you teach the course ? ( ) Yes ( ) No
If you do not, do you have any duties in connection with the course?
( ) Yes ( ) No
If yes, specify these duties: ______________________________

____

Name of Institution City State Zip Code

Return to B. C. Dodson, Chairman, Chemistry Department, Southern State College, Magnolia, Arkansas 71753

APPENDIX C

LIST OF INSTITUTIONS IN SAMPLE

UNIVERSITIES

Alabama, University of, Alabama
Alfred University, New York
Andrews University, Michigan
Arkansas, University of, Arkansas
Auburn University, Alabama
Baylor University, Texas
Boston University, Massachusetts
Bowling Green State University, Ohio
Bridgeport, University of, Connecticut
Brigham Young University, Utah
Brown University, Rhode Island
Bucknell University, Pennsylvania
California, University at Berkeley, California
California University at Los Angeles, California
Case Western Reserve University, Ohio
Catholic University of America, District of Columbia
Cincinnati University, Ohio
City University of New York, New York
City College, New York
Clemson University, South Carolina
Connecticut University of, Connecticut
Creighton University, Nebraska
Dayton, University of, Ohio
Delaware, University of, Delaware
Denver, University of, Colorado
De Paul University, Illinois
Detroit, University of, Michigan
Duke University, North Carolina
Duquesene University, Pennsylvania
East Tennessee State University, Tennessee
Eastern Michigan University, Michigan
Eastern New Mexico University, New Mexico
Fairleigh Dickinson University, New Jersey
Florida Agricultural and Mechanical University, Florida
Gonzaga University, Washington
Harvard University, Massachusetts
Idaho, University of, Idaho
Idaho State University, Idaho
Illinois Wesleyan University, Illinois
Indiana, University of, Pennsylvania
Iowa State University of Science & Technology, Iowa
Jacksonville University, Florida
John Hopkins University, Maryland
Kansas, University of, Kansas
Lehigh University, Florida
Long Island University, New York
Louisiana State University, Louisiana
Louisville, University of, Kentucky
Loyola University, Illinois
Loyola University of Los Angeles, California
Maine, University of, Maine
Marquette University, Wisconsin
Marshall University, West Virginia
Massachusetts, University of, Massachusetts
Michigan, University of, Michigan
Millikin University, Illinois
Mississippi, University of, Mississippi
Mississippi State University, Mississippi
Missouri, University of, Missouri
Montana, University of, Montana
Municipal University of Omaha, Nebraska
Nevada, University of, Nevada
New Hampshire, University of, New Hampshire
New York University, New York
Niagara University, New York
Loma Linda University, California
North Carolina at Chapel Hill, University of North Carolina
North Carolina State University at Raleigh, North Carolina
North Dakota, University of, North Dakota
North Texas State University, Texas

Northeastern University, Massachusetts
Northern Illinois University, Illinois
Northwestern University, Illinois
Notre Dame, University of, Indiana
Oklahoma City University, Oklahoma
Oklahoma State University, Oklahoma
Pacific Lutheran University, Washington
Pennsylvania, University of, Pennsylvania
Pennsylvania State University, Pennsylvania
Portland, University of, Oregon
Princeton University, New Jersey
Puget Sound, University of, Washington
Rice University, Texas
Roosevelt University, Illinois
Rutgers--The State University, New Jersey
St. Bonaventure University, New York
St. Louis University, Missouri
St. Mary's University, Texas
San Francisco, University of, California
Scranton, University of, Pennsylvania
Seattle University, Washington
South Dakota, University of, South Dakota
South Dakota State University, South Dakota
South Florida, University of, Florida
Southern California, University of, California
Southern Illinois University, Illinois
Southern Mississippi, University of, Mississippi
Southwestern Louisiana, University of, Louisiana
State University of New York, Albany, New York
State University of New York, Buffalo, New York
Stetson University, Florida
Syracuse University, New York
Temple University, Pennsylvania
Texas, University of, Texas
Texas A & M University, Texas
Texas Southern University, Texas
Texas Women's University, Texas
Toledo, University of, Ohio
Tulane University, Louisiana
Tulsa, University of, Oklahoma
Union College and University, New York
United States International University, California
Utah, University of, Utah
Vanderbilt University, Tennessee
Virginia, University of, Virginia
Washburn University of Topeka, Kansas
Washington, University of, Washington
Washington and Lee University, Virginia
Washington State University, Washington
Washington University, Missouri
Wayne State University, Michigan
West Virginia University, West Virginia
Western Illinois University, Illinois
Western Michigan University, Michigan
Wichita State University, Kansas
Willamettee University, Oregon
Wisconsin, University of, Wisconsin
Wittenberg University, Ohio
Xavier University, Ohio
Yale University, Connecticut
Youngstown State University, Ohio

LIBERAL ARTS COLLEGES

Alabama College, Alabama
Albany State College, Georgia
Amherst College, Massachusetts
Augustana College, South Dakota
Austin Peay State College, Tennessee
Baldwin-Wallace College, Ohio
Barnard College, New York
Bellarmine College, Kentucky
Bennett College, North Carolina
Bethel College, Tennessee
Brooklyn College, New York
Buena Vista College, Iowa
Cabrini College, Pennsylvania
California Baptist College, California
Carroll College, Wisconsin
Centenary College, Louisiana
Central Missouri State College, Missouri
Coe College, Iowa
Coker College, South Carolina
Colgate University, North Carolina
Columbia College, South Carolina
Concord College, West Virginia
Connecticut College, Connecticut
Converse College, South Carolina
Culver-Stockton College, Kentucky
Dana College, Nebraska
Davidson College, North Carolina
Doane College, Nebraska
East Texas Baptist College, Texas
Eastern Kentucky State College, Kentucky
Eastern Mennonite College, Virginia
Elizabethtown College, Pennsylvania
Emmanual College, Massachusetts
Hamline University, Minnesota
Hampton-Sydney College, Virginia
Hastings College, Nebraska
Holy Cross, College of the, Massachusetts
Holy Family College, Wisconsin
Hope College, Michigan
Howard Payne College, Texas
Illinois College, Illinois
Indiana Central College, Indiana
John Carroll University, Ohio
Judson College, Alabama
Kansas Weslyan University, Kansas
Kentucky State College, Kentucky
Lane College, Tennessee
Lincoln University, Missouri
Linfield College, Oregon
Loretta Heights College, Ohio
McPherson College, Kansas
Madison College, Virginia
Malone College, Ohio
Marietta College, Ohio
Marion College, Indiana
Massachusetts State College at Bridgewater, Massachusetts
Massachusetts State College at Westfield, Massachusetts
Merrimack College, Massachusetts
Monterey Institute of Foreign Studies, California
Mount Holyoke College, Massachusetts
Mount St. Joseph College, New York
Mount St. Mary's College, California
Mount St. Vincent's College, New York
Mount Union College, Ohio
Muhlenburg College, Pennsylvania
Mundelein College, Illinois
Murray State College, Kentucky
Nazareth College, Michigan
North Central College, Illinois
Notre Dame, College of, California
Notre Dame College, Ohio
Notre Dame College, Staten Island, New York
Oglethorpe College, Georgia
Olivet Nazarene College, Illinois
Otterbein College, Ohio
Ozarks, College of the, Missouri
Pacific Union College, California
Peru State College, Nebraska
Plymouth State College, New Hampshire
Queens College, North Carolina
Sacramento State College, California
St. Benedict, College of, Minnesota

St. Joseph College, Maryland
St. Mary of the Woods College, Indiana
St. Mary's College, Indiana
St. Michael's College, Vermont
St. Olaf College, Minnesota
St. Procopius College, Illinois
Salem College, West Virginia
San Francisco College for Women, California
San Jose State College, California
Santa Fe, College of, New Mexico
Seton Hall College, Pennsylvania
Shaw University, North Carolina
Shorter College, Georgia
South Carolina State College, South Carolina
Southern Connecticut State College, Connecticut
Southern Missionary College, Tennessee
Southern State College, Arkansas
Southwestern State College, Oklahoma
Southwestern University, Tennessee
Springhill College, Alabama
Sweet Briar College, Virginia
Tarleton State College, Texas
Trinity College, District of Columbia
Troy State College, Alabama
Ursuline College, Kentucky
Valdosta State College, Georgia
Wabash College, Indiana
Walla Walla College, Washington
Wayne State College, Nebraska
Waynesburg College, Pennsylvania
Westchester State College, Pennsylvania
Western Kentucky State College, Kentucky
Western Maryland College, Maryland
Wheeling College, West Virginia
Wilberforce University, Ohio
William College, Massachusetts
Williamantre State College, Connecticut
Wisconsin State University at Eau Claire, Wisconsin
Wooster, College of, Ohio

JUNIOR COLLEGES

Alice Lloyd College, Kentucky
Andrew College, Georgia
Armstrong State College, Georgia
Bennett College, New York
Black Hawk College, Illinois
Bluefield College, Virginia
Bronx Community College, New York
Cameron State Agricultural College, Oklahoma
Centralia College, Washington
Chabot College, California
Cisco Junior College, Texas
City College of San Francisco, California
Clatsop Community College, Oregon
Concordia College, Oregon
Contra Costa College, California
Cumberland College of Tennessee, Tennessee
Daniel Payne College, Alabama
Desert, College of the, California
Donnelly College, Kansas
El Camino College, California
Georgia Military College, Georgia
Georgia Southwestern College, Georgia
Grossmont College, California
Hibbing Junior College, Minnesota
Holmes Junior College, Mississippi
Illinois Valley Community College, Illinois
Independence Community College, Kansas
Indian River Junior College, Florida
Jackson Community College, Michigan
Jamestown Community College, New York
Joliet Junior College, Illinois
Kendall College, Illinois
Lansing Community College, Michigan
Lee College, Tennessee
Lee College, Texas
Lincoln College, Illinois
Los Angeles Valley College, California
Maricopa County Junior College, Arizona
Mercy Junior College, Missouri
Meridian Junior College, Mississippi
Mesa Junior College, Colorado
Midway Junior College, Kentucky
Mississippi Delta Junior College, Mississippi
Modesto Junior College, California
Mohawk Valley Community College, New York
Monterey Peninsula College, California
Morristown College, Tennessee
Mount San Antonio College, California
Multnomah College, Oregon
Murray State A & M College, Oklahoma
Norman College, Georgia
Oklahoma Military Academy, Oklahoma
Orange County Community College, New York
Packer Collegiate Institute, New York
Palo Verde College, California
Pine Manor Junior College, Massachusetts
Reinhardt College, Georgia
St. John's River Junior College, Florida
San Diego Junior College, California
Santa Barbara City College, California
Santa Monica City College, California
Snead College, Alabama
South Georgia College, Georgia
Southeastern Christian College, Kentucky
Southeastern Iowa College, Iowa
Southwest Texas Junior College, Texas
Sue Bennett College, Kentucky
Sullins College, Virginia
Tyler Junior College, Texas
Solana Junior College, California
Valley Forge Military Junior College, Pennsylvania
Ventura College, California
Victor Valley College, California
Vicennes University, Indiana
Westbrook Junior College, Missouri

SPECIALIZED INSTITUTIONS

Agricultural and Technical College of North Carolina, North Carolina
Aquinas Institute of Philosophy and Theology, Illinois
California Institute of Technology, California
Cheyney State College, Pennsylvania
Chicago State College, Illinois
Concordia Teachers College, Illinois
East Stroudsburg State College, Pennsylvania
Fashion Institute of Technology, New York
Illinois Institute of Technology, Illinois
Illinois State University, Illinois
Mansfield State College, Pennsylvania
Massachusetts State College at Salem, Massachusetts
Montclair State College, New Jersey
Newark College of Engineering, New Jersey
New Haven College, Connecticut
Oregon College of Education, Oregon
Polytechnic Institute of Brooklyn, New York
Pratt Institute, New York
Rochester Institute of Technology, New York
Rose Polytechnic Institute, Indiana
Saint Charles College, Maryland
Slippery Rock State College, Pennsylvania
South Dakota School of Mines and Technology, South Dakota
Trenton State College, New Jersey
United States Military Academy, New York

APPENDIX D

LIST OF COLLEGES USED IN VALIDATING QUESTIONNAIRE

LIST OF COLLEGES USED IN VALIDATING QUESTIONNAIRE

Agnes Scott College, Georgia
*Alliance College, Pennsylvania
*Alverno College, Wisconsin
Aquinas College, Michigan
*Anderson College, Indiana
Augustana College, Illinois
*Aurora College, Illinois
Barber-Scotia College, North Carolina
*Barry College, Florida
*Beaver College, Pennsylvania
*Belhaven College, Mississippi
*Beloit College, Wisconsin
*Bellarmine-Ursuline College, Kentucky
Bloomfield College, New Jersey
Bluffton College, Ohio
*Caldwell College for Women, New Jersey
California State College, Fullerton
*California State College, Hayward
*California State College, San Bernardino
Carson-Newman College, Tennessee
Carthage College, Illinois
Central Connecticut State College, Connecticut
College of Charleston, South Carolina
*Chatham College, Pennsylvania
*Chico State College, California
*Christian Brothers College, Tennessee
*Claremont Men's College, California
*Colby College, Maine
Concordia College, Minnesota
*Cumberland College, Kentucky
*Dallas, University of, Texas
*Dickinson College, Pennsylvania
*Dillard University, Louisiana
Dominican College, Wisconsin
Drury College, Missouri
*Duchesne College of the Sacred Heart, Nebraska
*Eastern Illinois University, Illinois
*Eastern Nazarene College, Massachusetts
*Eastern Washington State College, Washington
Emory and Henry College, Virginia
*Evansville College, Indiana (University of Evansville)
*Fairfield University, Connecticut
Fairleigh University, Connecticut
*Florence State College, Alabama
*Fontbonne College, Missouri
*Fort Hays State College, Kansas
Fort Lewis College, Ohio
Fort Wright College of the Holy Names, Washington
*Francis T. Nicholls State College, Louisiana
Franklin College of Indiana, Indiana
*Gallaudet College, District of Columbia
*Georgian Court College, New Jersey
*Goshen College, Indiana
Greensboro College, North Carolina
Hanover College, Indiana
*Hardin-Simmons University, Texas
*Harding College, Arkansas
*Hiram College, Ohio
*Hood College, Maryland
Humboldt State College, California
Hunter College, New York
*Huntington College, Indiana
*Idaho, College of, Idaho
*Kentucky Wesleyan College, Kentucky
La Salle College, Pennsylvania
Lander College, South Carolina
*Lewis and Clark College, Oregon
*Le Moyne College, Tennessee
Livingston College, North Carolina
Longwood College, Virginia
*Loras College, Iowa

*Manchester College, Indiana
*Manhattan College, New York
Marymount College, California
*Marymount College, Kansas
Maryville College, Tennessee
Massachusetts State College, Massachusetts
Mercyhurst College, Pennsylvania
*Middlebury College, Vermont
Mt. Angel College, Oregon
*Mount Marty College, South Dakota
Mount Mary College, Wisconsin
*Mount Mercy College, Iowa
*Nasson College, Maine
*Northwest Nazarene College, Idaho
*Norwich University, Vermont
*Notre Dame of Maryland College, Maryland
*Olivet College, Michigan
*Ouachita Baptist University, Arkansas
*Our Lady of the Lake College, Texas
*Pace College, New York
*Pfeiffer College, North Carolina
Pitzer College, California
Portland State College, Oregon
*Quincy College, Illinois
Radcliff College, Massachusetts
*Randolph-Macon Woman's College, Virginia
Reed College, Oregon
Regis College, Massachusetts
Ripon College, Wisconsin
Rocky Mountain College, Montana
*St. Ambrose College, Iowa
*St. Bernard College, Alabama
St. Edward University, Texas
*St. John Fisher College, New York
*St. John's University, Minnesota
*St. Martin's College, Washington
*St. Mary of the Plains College, Kansas
*St. Mary's College, Minnesota
St. Mary's University, Texas
St. Paul's College, Virginia
*St. Teresa, College of, Minnesota
St. Thomas, University of, Texas
*St. Vincent College, Pennsylvania
*Samford University, Alabama
*Seattle Pacific College, Washington
*San Fernando Valley State College, California
*Shimer College, Illinois
Simpson College, Iowa
*Southeastern State College, Oklahoma
*Southern California College, California
*Spelman College, Georgia
*Stanislaus State College, California
*State College at North Adams, Massachusetts
State College at Westfield, Massachusetts
*State University College, Buffalo, New York
*State University of New York, Binghamton
*Stephens College, Missouri
*Sterling College, Kansas
State University College at Geneseo, New York
Suffolk University, Massachusetts
*Tabor College, Kansas
Texas Wesleyan College, Texas
*The Citadel, South Carolina
*The College of St. Catherine, Minnesota
*Tougaloo College, Mississippi
Tusculum College, Tennessee
*Valley City State College, North Dakota
*Wake Forest State College, North Carolina
Warner Pacific College, Oregon
Wayne State College, Nebraska
Wells College, New York
West Texas State University, Texas
Westminister College, Utah
Wheaton College, Illinois
*Williams Woods, Missouri
*Wilmington College, Ohio
*Wisconsin State University, La Crosse, Wisconsin
*Wisconsin State University, Superior, Wisconsin
*Wofford College, South Carolina

*Colleges and Universities that responded. Percent response was 63 percent.

APPENDIX E

RAW DATA ON T-TEST SCORES

RAW DATA ON T-TEST SCORES

Table and Statement		Mean				Standard Deviation			
		Univ.	L. A.	J. C.	Spec.	Univ.	L. A.	J. C.	Spec.
15-A	a	.512	.636	.683	.583	.503	.484	.471	.515
	b	.134	.909	.732	.167	.343	.289	.264	.389
	c	.732	.364	.341	.833	.306	.667	.656	.289
	d	.854	.909	.000	.000	.281	.289	.000	.000
	e	.115	.584	.609	.100	.144	.978	.997	.113
	f	.268	.442	.171	.833	.446	.500	.381	.289
16-A	1	1.683	1.689	1.390	1.833	.701	.831	.666	.669
	2	1.451	1.403	1.366	1.500	.669	.712	.698	.718
	3	1.890	1.974	1.927	2.083	.832	.903	.906	.798
	4	1.695	1.584	1.586	1.667	.101	.978	.948	.793
	5	1.720	1.689	1.659	2.333	.920	.977	.965	.985
	6	2.390	2.404	2.805	2.333	.885	.799	.601	.651
20-A	1	.646	.753	.603	.833	.596	.566	.521	.937
	2	.646	.623	.609	.500	.506	.539	.542	.522
	3	.524	.571	.366	.667	.549	.524	.488	.651
	4	.659	.610	.659	.417	.652	.610	.530	.515
	5	.305	.403	.585	.333	.602	.591	.631	.651
	6	.756	.688	.634	.333	.432	.494	.623	.492
	7	.854	.779	.746	.767	.322	.315	.358	.389
	8	.183	.247	.365	.230	.447	.467	.381	.452
	9	.402	.532	.610	.583	.563	.598	.542	.515
	10	.415	.364	.512	.333	.647	.536	.675	.492
21-A	a	.890	.935	.927	.917	.314	.248	.263	.289
	b	.110	.420	.220	.250	.314	.352	.419	.452
	c	.195	.116	.171	.167	.398	.323	.381	.389
	d	.195	.169	.121	.250	.398	.377	.331	.452
	e	.012	.013	.000	.000	.110	.114	.000	.000
	f	.012	.026	.487	.000	.110	.160	.218	.000
	g	.049	.091	.220	.000	.216	.289	.419	.000
	h	.780	.922	.780	.916	.416	.269	.419	.289
	i	.695	.831	.780	.833	.463	.377	.419	.389
	j	.720	.831	.780	.833	.452	.377	.419	.389
	k	.671	.714	.707	.750	.473	.455	.461	.452
	l	.098	.909	.220	.833	.296	.299	.690	.289
23-A	a	.671	.345	.585	.917	.315	.501	.264	.289
	b	.268	.338	.244	.250	.315	.476	.419	.453
	c	.121	.143	.293	.166	.399	.352	.381	.389
	d	.232	.364	.244	.250	.399	.484	.331	.452

RAW DATA ON T-TEST SCORES

Table and Statement		Mean				Standard Deviation			
		Univ.	L. A.	J. C.	Spec.	Univ.	L. A.	J. C.	Spec.
23-A	e	.524	.481	.537	.000	.110	.503	.000	.000
	f	.085	.039	.073	.000	.110	.194	.208	.000
	g	.378	.494	.341	.000	.217	.303	.419	.000
	h	.585	.636	.683	.917	.416	.484	.419	.289
	i	.146	.129	.146	.083	.463	.338	.419	.389
26-A	1	.646	.753	1.341	.833	.595	.566	.521	.937
	2	.646	.623	1.073	.500	.549	.524	.488	.651
	3	.524	.571	1.024	.667	.549	.524	.488	.515
	4	.659	.610	1.073	.416	.652	.610	.529	.515
	5	.305	.403	1.586	.333	.002	.590	.631	.651
	6	.756	.688	1.707	.333	.432	.494	.623	.492
	7	.085	.078	1.561	.167	.322	.315	.358	.389
	8	.183	.247	1.488	.250	.448	.463	.581	.452
	9	.402	.532	2.073	.583	.563	.598	.542	.515
	10	.415	.364	1.073	.333	.647	.536	.675	.492
	11	1.829	2.091	1.463	1.833	1.570	1.624	1.112	1.586
	12	1.476	1.545	1.073	1.250	.593	.619	.480	.452
	13	1.037	1.078	1.219	1.000	.292	.315	.264	.000
	14	1.073	1.052	1.146	1.000	.344	.223	.156	.000
	15	1.085	1.078	1.390	1.333	.358	.270	.264	.493
	16	1.671	1.727	1.121	1.833	.568	.504	.547	.577
	17	1.732	1.767	1.363	2.000	.668	.626	.642	.738
	18	1.866	1.857	1.244	1.833	.643	.601	.634	.718
	19	1.439	1.597	1.414	1.333	.611	.748	.553	.492
	20	2.354	2.402	1.634	2.417	.674	.391	.519	.669
	21	1.170	1.182	1.341	1.250	.466	.388	.345	.452
	22	1.732	1.766	1.414	1.583	.629	.535	.595	.515
	23	1.109	1.091	1.313	1.000	.416	.289	.264	.000
	24	1.341	1.286	.000	1.083	.526	.535	.419	.289
35-A	1	.024	.753	.854	.833	.155	.566	.358	.389
	2	.366	.623	.024	.000	.484	.539	.156	.000
	3	.305	.571	.073	.250	.463	.524	.263	.452
	4	.280	.610	.220	.083	.452	.610	.419	.288
	5	.195	.402	.756	.750	.398	.591	.434	.452
	6	.232	.688	.171	.000	.425	.494	.380	.000
	7	.110	.078	.902	.833	.315	.315	.300	.389
	8	.280	.247	.756	.750	.452	.463	.434	.452
	9	.158	.532	.975	.833	.367	.598	.156	.389
	10	.122	.364	.707	.667	.329	.162	.460	.492
	11	.159	.209	.146	.083	.367	.619	.357	.289

RAW DATA ON T-TEST SCORES

Table and Statement		Mean				Standard Deviation			
		Univ.	L. A.	J. C.	Spec.	Univ.	L. A.	J. C.	Spec.
35-A	12	.268	.155	.220	.083	.446	.315	.419	.289
	13	.256	.108	.220	.250	.439	.223	.419	.452
	14	.512	.105	.098	.000	.503	.270	.300	.000
	15	.354	.108	.073	.167	.481	.504	.264	.389
	16	.231	.173	.146	.250	.424	.626	.357	.452
	17	.500	.177	.219	.333	.503	.601	.419	.492
	18	.378	.186	.171	.083	.488	.748	.380	.289
	19	.256	.160	.561	.583	.439	.590	.502	.515
	20	.439	.240	.268	.083	.499	.388	.449	.289
	21	.122	.118	.000	.000	.329	.535	.000	.000
38-A	a	.512	.207	.756	.416	.503	.408	.111	.514
	b	.354	.545	.244	.167	.418	.501	.434	.389
	c	.232	.429	.292	.083	.425	.498	.460	.289
	d	.500	.234	.512	.583	.503	.426	.506	.515
	e	.378	.623	.512	.417	.488	.488	.506	.515
	f	.256	.532	.317	.167	.439	.502	.471	.389
	g	.439	.260	.439	.250	.499	.441	.502	.452
39-A	1	.537	.532	.363	.667	.502	.502	.488	.492
	2	.366	.312	.414	.333	.404	.406	.499	.492
	3	.048	.130	.244	.167	.217	.338	.435	.389
	4	.317	.273	.293	.250	.468	.448	.461	.452
	5	.243	.065	.146	.083	.155	.248	.357	.289
	6	.365	.286	.341	.083	.485	.454	.480	.289
	7	.304	.376	.366	.417	.463	.488	.488	.515
	8	.280	.246	.293	.417	.452	.434	.460	.515
	9	.195	.338	.244	.333	.398	.476	.434	.492
	10	.232	.220	.220	.230	.425	.417	.419	.452
	11	.110	.208	.293	.333	.315	.408	.461	.492
	12	.280	.312	.439	.250	.452	.466	.302	.452
	13	.158	.221	.146	.250	.367	.417	.358	.452
	14	.122	.234	.195	.333	.329	.426	.401	.492
	15	.158	.130	.220	.333	.367	.338	.419	.492
	16	.268	.649	.122	.250	.445	.248	.331	.452
	17	.256	.208	.293	.333	.439	.408	.401	.289
41-A	A	1.926	1.779	1.951	1.583	.979	.926	.740	.900
	B	1.537	1.364	1.220	1.333	.878	.793	.725	.778
	C	1.671	1.480	1.195	1.167	.917	.771	.679	.718
	D	1.488	1.338	1.439	1.333	.850	.699	.776	.651
	E	1.268	1.312	1.170	1.417	.817	.748	.667	.900

APPENDIX F

TEXTBOOKS AND SYSTEMS APPROACH

TEXTBOOKS AND SYSTEMS APPROACH

The interested reader is referred to an article entitled "Chemical Publishers Push Teaching Aids" for a review of the best-selling general chemistry textbooks and a discussion of the systems or "package" approach to teaching freshman chemistry. The systems approach is designed to fill a need of the sorely pressed and harried teacher of general chemistry who needs teaching aids to supplement the textbook. Some of the best-selling general chemistry textbooks were listed as follows:*

Author(s)	Publisher
M. A. Sienko and R. A. Plane	McGraw Hill (two textbooks)
C. E. Mortimer	Reinhold
H. P. Gray and G. P. Haight	W. A. Benjamin
C. H. Sorum	Prentice-Hall
R. Johnson and E. Grunwald	Prentice-Hall
C. W. Keenman and J. H. Wood	Harper and Row
J. Quagliano	Prentice-Hall

Dissatisfaction with the laboratory in freshman chemistry was revealed by an unpublished survey by Harper and Row in 1967. The survey finding prompted them to develop a series of laboratory "separates." This series consists of separate laboratory experiments in general chemistry, each written and tested by college and university chemistry professors.#

*Not listed according to sale.

#"Chemical Publishers Push Teaching Aids," Chemical and Engineering News, 46, August 19, 1968, pp. 32-35.

APPENDIX G

RAW DATA

TABLE A. RAW DATA ON THE NUMBER OF TEACHER RESPONSES TO QUESTIONS RELATING TO COURSE AND TEXTBOOK CHANGES

Types of Changes	Number of Institutions Responding														
	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	Y[a]	N[b]	U[c]	Y	N	U	Y	N	U	Y	N	U	Y	N	U
1. Have the content and program of instruction been considerably modified but the framework of the old course retained?	46	33	3	51	23	3	26	14	1	5	5	2	128	75	9
2. Do you rely mainly upon a single textbook and laboratory manual in the new or revised course?	51	30	1	44	31	2	23	17	1	6	6	0	124	84	4
3. Are you using an outline or syllabus which was prepared especially for the new course?	39	41	2	42	34	1	15	26	0	6	5	1	102	106	4
4. Does the new course attempt to treat much of the traditional content such as the study of gases, liquids, solids, etc. as separate units?	38	36	8	37	35	5	25	15	1	5	7	0	105	93	14
5. Do you expect more reading outside the text in the new or revised course than in the old course?	16	62	4	23	50	4	18	20	3	2	9	1	59	141	12
6. Is the work in the new or revised course independent of collaboration with physicists?	62	20	0	51	25	1	20	18	3	4	8	0	137	71	4

TABLE A. (Continued)

Types of Changes	Number of Institutions Responding														
	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	Y	N	U	Y	N	U	Y	N	U	Y	N	U	Y	N	U
7. In the new or revised course has your department prepared a list of independent studies or research requiring investigations which can be carried on by the individual student outside the classroom and/or laboratory?	5	76	1	4	72	1	6	35	0	2	10	0	17	193	2
8. Has your department prepared special tests or other means of evaluating student achievement of the distinctive aims for the new or revised course?	11	69	2	17	59	1	11	28	2	3	9	0	42	165	5
9. Does your new and/or revised course have a set of objectives which have been formally stated and to which all members teaching the course have access?	27	52	3	33	40	4	23	17	1	7	5	0	90	114	8
10. Do the objectives of the new and/or revised course differ substantially from the objectives of the older course?	23	54	5	24	51	2	13	24	4	4	8	0	64	137	11

[a]Y - Yes

[b]N - No

[c]U - Uncertain

TABLE B. RAW DATA ON THE NUMBER OF TEACHER REACTIONS TO STATEMENTS CONCERNING THE CONVENTIONAL COURSE IN COLLEGE CHEMISTRY

The "conventional course in college chemistry:	Universities			Liberal Arts			Jr. Colleges			Specialized			All Inst.		
	A[a]	D[b]	U[c]	A	D	U	A	D	U	A	D	U	A	D	U
1. is generally satisfactory for all students.	22	48	8	31	31	12	12	20	8	6	5	1	71	104	29
2. is more appropriate for students who major in chemistry than those who do not.	31	40	9	30	29	14	23	14	2	4	6	2	88	89	27
3. could be significantly modified for the superior student with a good high school background in science and mathematics by eliminating descriptive matter and introducing more advanced non-traditional topics.	44	30	5	44	23	6	28	8	4	8	2	2	124	63	17
4. needs new textbooks of varying difficulty but adhering to traditional topics stressing the products of chemistry.	15	43	18	11	36	23	9	17	12	3	5	4	38	101	57
5. should be taught from textbooks of varying difficulty but utilizing the inquiry approach, i.e., stressing the processes of chemistry.	34	15	25	41	9	21	24	4	11	5	3	3	104	31	60
6. will continue because the time and cost are essential factors which have tended to retard the introduction of chemistry innovations analagous to CBA and CHEM study at the introductory college level.	28	28	19	22	27	18	13	14	9	1	6	5	64	75	51

[a]A - Agree [b]D - Disagree [c]U - Uncertain

APPENDIX H

COMPUTER PROGRAM

```
// JOB
// FOR                   BROWN DODSON
*IOCS(1132 PRINTER, CARD,DISK,TYPEWRITER,KEYBOARD)
*ONE WORD INTEGERS
**        DODSON PROGRAM STD,MEAN, CORR MATRIC
      DEFINE FILE 1(240,320,U,NX)
      DIMENSION XIMP(160),LCT(10), TEMP(10,8),L(8),DAT(212,8)
     1,X(212,8), C(8,8),SX(8),STD(8)
      EQUIVALENCE (DAT(212,8),X(212,8))
      M=8
C CHANGE NYZ TO EQUAL THE NO OF VARR. YOU HAVE
C  FORMAT 2 MUST FIT YOUR DATA
      NX=1
      NXX=1
      NZZ=1
      NYZ=116
3     READ(2,2)(XIMP(IZ),IZ=1,NYZ)
2     FORMAT(3X,F1.0,F4.C,F1.0,5F2.0,4X,F1.0,5F2.0,41F1.0/3X,F2.0,29F1.0
     1,3X,24F1.0,5F2.0,F1.0,F1.0///)
      WRITE(1'NX)XIMP
      CALL LCARD(LA)
      GO TO (3,4),LA
4     N=NX-1
      XN=N
5     WRITE(1,7)N
7     FORMAT(I2,'CARDS HAVE BEEN READ'//'TYPE THE 8 VAR. NO YOU WANT COR
     1R.(I3) ')
      CALL DATSW(7,ND)
      GO TO (500,601),ND
601   READ(6,8)(L(MM),MM=1,8)
8     FORMAT(I3)
600   DO 9 JX=1,N
      READ(1'JX)XIMP
      DO 109J=1,M
      LA=L(J)
      X(JX,J)=XIMP(LA)
109   DAT(JX,J)=XIMP(LA)
9     CONTINUE
      CALL DATSW (4,ND)
      GO TO (878,877),ND
877   WRITE(3,60) L
60    FORMAT(1H0,1X,'VARR', 8I13)
878   GO TO 100
1001  CALL DATSW (6,ND)
      GO TO (300,301),ND
300   WRITE(3,61) L
61    FORMAT(1H0,40X,'FREQUENCY DISTRIBUTION'//1X,'VARR',8I13)
      DO 42 K=1,M
      DO 40 J=1,10
40    LCT(J)=0
      DO 41 J=1,N
      IP=DAT(J,K)+1.5
      IF(IP-10)41,400,400
400   IP=10
41    LCT(IP)=LCT(IP)+1
      DO 62 J=1,10
62    TEMP(J,K) =LCT(J)
42    CONTINUE
      DO 63 J=1,10
      JJ=J-1
```

```
      WRITE(3,65) JJ, (TEMP(J,K), K=1,8)
65    FORMAT(1H0,1X, I4,8F13.0)
      DO 64 KK=1,M
64    TEMP(J,KK)=TEMP(J,KK) / XN
63    WRITE(3,66)(TEMP(J,NN),NN=1,8)
66    FORMAT(1H ,1X,'PERCENT',1X,8F13.2)
301   CALL DATSW (7,ND)
      GO TO (500,302),ND
500   IF(NXX-NYZ)513,5,5
513   NXZ= NXX
      INDX=2
      NZZ=NZZ+(M-1)
      IF (NZZ-NYZ) 511,511,510
510   L(1)=NXZ
      NXX=NXZ+1
      NCONT=NZZ-(M-2)
      DO 502  II=NCONT,NYZ
      L(INDX)=II
502   INDX=INDX+1
      NZZ=NXX
      IF(NZZ-NYZ)600,302,302
511   L(1)=NXZ
      NCONT=NZZ-(M-2)
      DO 512  II=NCONT,NZZ
      L(INDX)=II
512   INDX=INDX+1
      GO TO 600
302   CALL DATSW (8,ICK)
      GO TO (29,600),ICK
29    CALL EXIT
100   CALL DATSW(1,ND)
      GO TO (14,16),ND
14    WRITE(1,15)
15    FORMAT('DATSW 1 CYCLES'/6X,'2 SUMX'/6X, '3 STD'/             6X,'4 C
     1ORR MATRIC'/6X,'5 MEANS'/6X'6 SUMX**2 AND SUM X*Y'/ 6X,'7 AUTOMATI
     3C'/6X,'8 ON AND 7 OFF WILL TERMINATE THE PROGRAM'/6X,'9 WILL TAKE
     4 THE PROGRAM OUT OF AUTOMATIC'/ 6X, 'SET DATSWS AND PUSH START')
      PAUSE 2222
16    MM=0
      XN=N
      DO 1 IT=1,M
      SX(IT)=0.0
      DO 1 J=1,N
1     SX(IT)=SX(IT)+X(J,IT)
      DO 51IT=1,M
      LIT=IT
      DO 51J=LIT,M
      C(IT,J)=0.0
      DO 51K=1,N
51    C(IT,J)=C(IT,J)+X(K,IT)*X(K,J)
      DO 6 IF=1,M
      FACI= XN*C(IF,IF)-SX(IF)**2
      IP=IF+1
      DO 6 J=IP,M
6     C(IF,J)=(XN*C(IF,J)-SX(IF)*SX(J))/SQRT((XN*C(J,J)-SX(J)**2)*FACI)
      CALL DATSW(2,ND)
      GO TO (69,68),ND
69    MM=MM+1
      WRITE(3,10) SX
```

```
10      FORMAT(1H0, 1X,'SUMX',2X, 8(E13.7, 1X))
68      CALL DATSW(3,ND)
        GO TO (81,85),ND
81      DO 91K=1,M
91      STD(K)=SQRT((C(K,K)/XN)-(SX(K)/XN)**2)
        WRITE(3,101)  STD
101     FORMAT(1H 1X,'STD     ',8F13.3)
85      CALL DATSW (5,ND)
        GO TO (90,82),ND
90      MM=MM+1
        WRITE(3,93)(C(J,J), J=1,M)
93      FORMAT(1H ,1X,'SUMSQ',1X,8(E13.7,1X))
82      CALL DATSW (4,ND)
        GO TO (70,71),ND
70      MM=MM+1
        WRITE(3,22)L
22      FORMAT(1H0,15X,'I N T E R C O R R  M A T R I C',//8X,8(2X,I11))
        DO 701IAP=1,M
701     C(IAP,IAP)=1.0
        NZ=0
        CALL DATSW(7,ND)
        GO TO (821,819),ND
821     WRITE(3,822)(C(1,J),J=1,M)
822     FORMAT(1H0,14X,8(E10.3,3X))
        GO TO  71
819     DO 811 IXT=1,M
        NZ=NZ+1
25      FORMAT(1H0,1X,I4,9X,8(F10.5,3X))
811     WRITE(3,25)L(NZ),  (C(J,IXT),J=1, NZ)
71      CALL DATSW(5,ND)
        GO TO (72,73),ND
72      MM=MM+1
        DO 74 I=1,M
74      STD(I)=SX(I)/XN
        WRITE(3,75) STD
75      FORMAT(1H0,1X,'MEANS',2X,8F13.3)
73      IF (MM)77,77,79
77      WRITE(1,78)
78      FORMAT('TURN ON DATA SWITCH 1 AND PUSH START')
        PAUSE 3333
        CALL DATSW (9,NOVER)
        GO TO (999,5),NOVER
999     CALL DATSW (1,ND)
        GO TO (350,79),ND
350     GO TO 100
79      GO TO 1001
        END
```

```
// JOB
// FOR
*IOCS(1132 PRINTER, CARD, TYPEWRITER , KEYBOARD)
*ONE WORD INTEGERS
**      DODSON T SCORES
      DIMENSION        XTOT(500), YTOT(500), STDA(500),STDB(500)
     1,X(500)
1000  NVAR=207
      XNA=0.0
      XNB=0.0
      DO 1 J=1,NVAR
      XTOT(J)=0.0
      YTOT(J)=0.0
      STDA(J)=0.0
1     STDB(J)=0.0
10    READ(2,2)(X(K),K=1,NVAR)
2     FORMAT(3X,F1.0,F4.0,F1.0,5F2.0,4X,F1.0,5F2.0,41F1.0/3X,F2.0,29F1.0
     1,3X,24F1.0,5F2.0,F1.0,F1.0/3X,30F1.0,F2.0,23F1.0/3X,17F1.0,9X,8F1.
     20,2X,6F1.0,6X,19X,6F1.0/)
C  LOAD GROUPS ONE AT A TIME
C  FORMAT 2 MUST FIT YOUR DATA CARDS
C  NVAR MUST EQUAL THE NO OF VARIABLES
      XNA=XNA+1.0
      DO 3 J=1,NVAR
      XTOT(J)=XTOT(J)+X(J)
3     STDA(J)=STDA(J)+X(J)**2
      CALL LCARD(NXN)
      GO TO (10,4),NXN
4     WRITE(1,5)
5     FORMAT('RUN OUT CARDS AND LOAD HOPPER WITH SECOND GROUP')
      PAUSE
6     READ(2,2) (X(K),K=1,NVAR)
      XNB=XNB+1.0
      DO 7 J=1,NVAR
      YTOT(J)=YTOT(J)+X(J)
7     STDB(J)= STDB(J)+X(J)**2
      CALL LCARD(NX)
      GO TO (6,9),NX
9     WRITE(3,200) XNA,XNB
200   FORMAT(1H1,4X,  'GROUP(1) N=',F10.0/ 4X,  'GROUP(2) N=', F10.0//
     11X, 'VARIABLE', 5X, 'SUM(1)**2', 4X,'SUM(2)**2', 4X, 'MEAN GR(1)', 4X
     2 4X,'MEAN GR(2)', 4X,'STD GR(1)', 5X, 'STD GR(2)',5X,'T SCORES',/)
      DO 11 K=1,NVAR
      STDAS=SQRT(((XNA*STDA(K)-XTOT(K)**2)/XNA**2)*(XNA/(XNA-1.0)))
      STDBS=SQRT(((XNB*STDB(K)-YTOT(K)**2)/XNB**2)*(XNB/(XNB-1.0)))
      XAV=XTOT(K)/XNA
      YAV=YTOT(K)/XNB
      SIGMA=SQRT((XNA*STDAS**2+XNB*STDBS**2)/(XNA+XNB-2.0))
      TSC=(XAV-YAV)/(SIGMA*SQRT(1.0/XNA+1.0/XNB))
11    WRITE(3,100)K, XTOT(K), YTOT(K), XAV,YAV, STDAS,STDBS,TSC
100   FORMAT(1H , 1X,I4,2X,2(E14.7,2X),2(E14.7,2X),2(E14.7,2X),F14.4)
      WRITE(1,101)
101   FORMAT('IF MORE GROUPS ARE TO BE RUN , RUN OUT CARDS AND LOAD HOPPER
     1ER'/'TURN ON DATA SWITCH 1 AND PUSH START'/'PUSH START TO END PROG
     2RAM WITH DATSW 1 OFF')
      PAUSE
      CALL DATSW(1,LAST)
      GO TO (1000,1001),LAST
1001  CALL EXIT
```

```
      END

// XEQ LIST
```