AN ABSTRACT OF THE THESIS OF

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Purpose of the Study

In most liberal arts colleges, the majority of students enrolled are primarily interested in a liberal education. To meet the requirements of its students, several colleges have introduced a relatively new program in the sciences; this program is the integrated science course. This study attempts to evaluate an integrated physics-chemistry course in a liberal arts college.

Procedure

Four liberal arts colleges, ranging in size from 700 to 1000 students, were chosen to furnish the population groups for this study. The control group, 94 students, consisted of students enrolled in a course in general chemistry in three liberal arts colleges. The experimental group, 83 students, consisted of students enrolled in an

integrated course in physics and chemistry in Tarkio College.

Following one academic year of instruction, the population groups were administered two tests. The tests used were: Watson-Glaser Critical Thinking Appraisal (CTA), Form Ym, and 2) American Chemical Society (ACS) Cooperative Examination in General Chemistry, Form 1965. The ACS test was divided into sub-tests in order to get a more accurate measure of the achievement in chemistry.

The area of chemistry was chosen as the course content to be measured, largely owing to the availability of an adequate test to measure chemistry achievements.

Findings

The following conclusions were drawn from the analysis of the data:

1. The control group (chemistry students) was superior in its knowledge of chemistry as compared with the experimental group (integrated physics-chemistry students). This superiority was exhibited by higher scores on the ACS test and the sub-tests of the ACS test.
2. The control group was superior to the experimental group in the area of critical-thinking as exhibited by the CTA test.
3. The integrated physics-chemistry course of two-semester

duration did not adequately prepare the students for the test used in the area of chemistry. The basis for this finding was the comparison of the integrated group to the chemistry group.

4. To adequately evaluate the integrated physics-chemistry program, the program should be of two years duration, and student achievement should be compared with that of students who have completed one year each of college chemistry and physics.

Recommendations

As a result of this study, the following recommendations were made:

1. The integrated course should be studied on the basis of two, three and four terms in length.
2. A study should be made that would compare the integrated course with both physics and chemistry courses.
3. A study should be made of the student in a physics-chemistry course subsequent to his completion of the integrated program to determine whether the integrated course adequately prepares the student for advanced work.
4. A study should be made of different techniques of teaching the integrated course.

An Integrated Physics-Chemistry Course in a Liberal Arts College

by

Harold LeRoy McIntosh

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CHAPTER I

INTRODUCTION

The enormous expansion of knowledge, particularly in the sciences, in the past two decades has revolutionized science teaching in secondary schools and colleges. Information is increasing at such an accelerating pace that an individual in any one field of study has difficulty keeping current. It is becoming increasingly clear that with so much to teach, one cannot afford unnecessary duplication in subject matter. The integration of two or more courses into a single unit reduces this duplication. In this study a course with the integration of physics and chemistry was examined.

Schilling in Fuller (20) spoke of integration in science as follows (20, p. 7):

> My thesis is (a) that science education has responsibilities with respect to some extremely important trans-disciplinary problems to which it has paid virtually no attention, (b) that its educational theory and practice need to be adjusted to take these into account, (c) that the basic and unique meaning or value of interdisciplinary thought and study residues in its being the only available approach to the solution of such problems. If what I have to say makes any sense, our interdisciplinary ventures must go far beyond the collaboration of chemists and physicists, though if they lead out in such undertakings, half of the battle will have been won.

> To clarify terminology I suggest that the term inter-disciplinary be taken to signify an intellectual undertaking that employs the resources of several disciplines to perform tasks that no one of them can handle alone. It requires the collaboration of experts from different fields who are willing to violate the boundaries ordinarily separating them.

The relationships between physics and chemistry that allow for their integration became apparent during the past few decades. The possibility of teaching the introductory courses in physics and chemistry in a more efficient and effective manner by integrating the content has been considered by several colleges since the early 1950's.

In 1961, a conference was held at Beloit, Wisconsin, in order to bring together a group of people who were concerned about the integration of chemistry and physics. Fuller (20), the director of the conference, spoke of the integrated course as follows (20, p. 5):

> Several aspects of modern physics at the introductory level require the student to think in terms of atoms and molecules. Learning some basic concepts along with physics enables the student to grasp more effectively the physical principles involved. The blending of chemistry with physics is most obvious in studies of the structure of matter and its interactions with energy in the form of heat, electricity and electromagnetic radiations.
>
> If the beginning student is to understand the fundamental interdependence of modern chemistry and physics, he should be introduced to these sciences in an integrated course.

Fuller identified some topics such as heat and electricity that are common to both physics and chemistry. Other topics which bridge the gap between the two disciplines are: 1) Energy,

2) Momentum, 3) Electrodynamics, 4) Wave Motion and 5) Force Fields.

It is not possible to teach chemistry at any level and not include some of the concepts of physics in the process. The field of chemistry has grown to such an extent that it is futile to introduce a student in his first year of college to the vast amount of knowledge in this field.

The essence of modern chemistry can be appreciated and perceived by the student only as he grasps the principles to which he relates the facts. Many of these principles are derived from physical concepts. The pace at which modern theories of chemistry are developing demands of the chemistry student a knowledge of physics.

Most schools using the integrated course are using two textbooks, one in each discipline. Many teachers feel that this is not integration in the true sense. For this reason some new texts are being developed in which the material from both disciplines is integrated into a single volume. The Bryn Mawr College science faculty, with aid from the National Science Foundation, has written an experimental text (29) that is specifically designed for an integrated course in physics and chemistry. The writing of such a text is not an easy task, since it represents a bold departure from the conventional. The text written by the Bryn Mawr faculty is a two-volume text and is adequate.

Purpose of the Study

There are about 50 colleges in the United States that have an integrated physics-chemistry course in their curriculum. The following colleges were among the first to attempt this type of program.

Bryn Mawr College	Bryn Mawr, Pennsylvania
Beloit College	Beloit, Wisconsin
Reed College	Portland, Oregon
Wabash College	Crawfordsville, Indiana

Because there are so many schools using this type of course and because of the possibility of more schools adopting it in the near future, this investigator believed that a study was needed in order to evaluate such a program in a liberal arts college.

The purpose of this study is to compare the mastery of subject matter studied and critical-thinking abilities developed between students who studied chemistry in an integrated physics-chemistry course and students in a conventional chemistry course.

More specifically, answers to the following questions were sought in this study:

1. To what extent do students who study in a conventional chemistry course differ in course content mastered from students who study in an integrated physics-chemistry course?

2. To what extent do these same two groups differ in the development of critical thinking abilities?

Scope of the Study

This study utilized two standardized tests and their sub-tests to measure differences between a group of college students who studied in a conventional chemistry course in three small liberal arts colleges and a group of students who studied in an integrated physics-chemistry course in one small liberal arts college. The study was designed to yield information concerning the achievement of the population groups in chemistry course content and in the development of critical-thinking abilities. This information allowed for an evaluation of the integrated course with respect to the areas tested and the population groups used.

Justification of the Study

When one introduces an innovation in the learning process there should be a method whereby an evaluation can be made. A search of the literature did not indicate that a study of an integrated physics-chemistry course in a liberal arts college had been made. Therefore, this study was needed to present such an evaluation.

Significance of the Study

There have been a number of studies made to determine the nature of course content mastered in physics and chemistry when certain factors were introduced. There have been studies on critical-thinking abilities developed by students in both physics and chemistry with several variables present.

There has been only one study reported since 1940 on the use of an integrated physics-chemistry course (14) at the secondary school level. There have been no studies published on the evaluation of an integrated physics-chemistry course in a liberal arts college specifically based on course-content achievement and critical-thinking abilities.

The above information was accumulated by this investigator in a literature search that included such publications as The Education Index and Datrix, the latter a research service provided by Xerox Corporation and University Microfilms Library Service.

This study may provide information of interest to the 50 or more colleges now using the integrated course and to others that plan to adopt it in the future.

Definition of Terms

Academic year - The use of the term "academic year" refers to two semesters. This was the length of time the students used in this study were in their respective classes.

Achievement in course content - This phrase is used to denote the extent to which the student had mastered the content of a college course and is measured by the score on the ACS Cooperative Examination in General Chemistry, Form 1965.

Critical-thinking abilities - Critical-thinking ability is a composite of skills that include the following as stated by the authors of the test used in this study (44):

1. The ability to define a problem.
2. The ability to select pertinent information for the solution of a problem.
3. The ability to recognize stated and unstated assumptions.
4. The ability to formulate and select relevant and promising hypotheses.
5. The ability to draw conclusions validly and to judge validity of inferences.

Integrated - The World Book Dictionary definition of this word states, "the bringing together of parts into a whole" (2). In this study the above definition is precisely what is used. When the phrase "integrated physics-chemistry course" is used, it refers to a course taught to college students wherein principles and concepts of physics and chemistry are brought together to show that they have a close relationship. An outline of this course is found in Appendix D.

Liberal arts college - The use of the term "liberal arts college" is meant to convey the idea of a school that has as its principle goal the teaching of various courses for their cultural value rather than immediate practical use. Schools of this type generally are privately endowed, and most are denominational rather than secular.

Population groups - The population groups used in this study are the following: 1) Control group, a group of students from three liberal arts colleges, all denominational, that were enrolled in a conventional chemistry course; 2) Experimental group, a group of students from one liberal arts college, denominational, that were enrolled in an integrated physics-chemistry course.

The reasons for the choice of the schools involved in the study are:

1. The schools that offer an integrated physics-chemistry course are limited in number and only one of several contacted agreed to participate in the study.
2. The schools that participated are very similar in their entrance requirements and their basic objectives.

Tests - The tests used as measurement tools in this study are as follows:

1. Watson-Glaser Critical-Thinking Appraisal, Form Ym
2. ACS I, the ACS Cooperative Examination in General Chemistry, Form 1965
3. ACS II, selected items from the ACS Cooperative Examination in General Chemistry, Form 1965
4. ACS III, selected items from the ACS Cooperative Examination in General Chemistry, Form 1965
5. ACS IV, selected items from the ACS Cooperative Examination in General Chemistry, Form 1965

The selected items used in tests three through five were chosen by this investigator and two members of the Chemistry Department at Tarkio College, Tarkio, Missouri.

Hypotheses

The hypotheses of this study are stated in null form as follows:

1. There is no difference in the critical-thinking abilities between the control group and the experimental group.

Hypotheses two through five are of the same form but reflect the differences in tests used to measure different aspects of achievement in chemistry.

2. There is no difference in the achievement in chemistry as measured with the ACS I test, between the control group and the experimental group.

3. There is no difference in the achievement in chemistry as measured with the ACS II test, between the control group and the experimental group.

4. There is no difference in the achievement in chemistry as measured with the ACS III test, between the control group and the experimental group.

5. There is no difference in the achievement in chemistry as measured with the ACS IV test, between the control group and the experimental group.

Assumptions

The assumptions of this study are:

1. There are no differences in the academic abilities between the two population groups (control group and experimental group) prior to entering this research study.

2. The ACS Cooperative Examination in General Chemistry, Form 1965, is an adequate test to measure the chemistry content mastered by the students in the population groups.

3. The Watson-Glaser Critical-Thinking Appraisal, Form Ym, is an adequate test to measure the critical-thinking

abilities developed by the students in the population groups.

4. The five percent level of significance is adequate for testing the tenability of the hypotheses in this study.

Limitations

The limitations of this study are as follows:

1. Only one college was used to form the experimental group.
2. Only three colleges were used to form the control group.
3. Chemistry was the only area of comparison in course mastery.
4. A pretest was not used.
5. The groups were compared on a basis of subject matter mastered by the ACS Test and critical-thinking ability developed as measured by the Watson-Glaser Critical-Thinking Appraisal only.

Chapter II

REVIEW OF LITERATURE

A review of the literature on integrated courses revealed several publications on different aspects of the problem. However, there has been only one published thesis of a nature similar to the present study. The aforementioned thesis was conducted at the secondary school level, whereas this study was conducted at the college level.

In this chapter, the following topics are reviewed as they relate to the study under investigation. They are:

1. Integrated science courses in secondary schools.
2. Integrated science courses in higher education.

Integrated Science Courses in Secondary Schools

Integrated science courses as separate subjects had their beginning sometime during the first decade of this century. As with most innovations in teaching and curriculum development, they began in the elementary and secondary schools. Noll (36) said that integrated science courses were berated and despised by those who opposed their beginning, but they have gained ground steadily through the years. Noll was referring to a survey course called "General Science," which up until the middle 1950's was a popular science course in secondary schools.

The general science course was able to give a high degree of exposure in science to the average secondary school student.

An analysis of the "General Science Course" showed it to be unpopular with teachers and students for the following reasons:

1. The course was essentially a hodge-podge of courses such as: a) physics, b) chemistry, c) biology, d) astronomy, e) zoology, f) hygiene, g) geology, and others.
2. There seemed to be some difficulty in maintaining a continuity in the course as a result of so many diverse topics.
3. An emphasis was placed on breadth of subject matter covered rather than depth of understanding.
4. Most schools did not use laboratory exercies in the course.

The advent of "Sputnik" in 1957 started a revolution that caused several influential persons and groups to take a closer look at the science curricula in secondary schools.

In recent years, several high schools and private colleges have begun to experiment with integrating only two disciplines in a single course. Lerner (30) told of the program used at Newark, New Jersey, that was initiated in 1960, where chemistry and physics were integrated and taught in a two-year sequence. Lerner indicated the need for such a program was largely due to the massive shake-up in high school science curricula as a result of extensive studies by such groups as: a) American Association for the Advancement of

Science (AAAS), b) American Chemical Society (ACS), c) American Association of Physics Teachers (AAPT), and d) National Science Foundation (NSF).

Before embarking on the experimental course, Lerner considered two possible areas where problems may occur, 1) availability of trained and competent teachers, and 2) problems related to the laboratory sessions. In the school where Lerner worked there seemed to be no problem with the first question as there were three competent teachers available. Concerning the second question, Lerner reported that they were also fortunate. The school administration furnished a large laboratory space and special laboratory assistants to help carry out the program.

Results of Tests of Students in Integrated Science (Two Year Combined Course) and for Students Taking Separate Courses Consecutively (30, p. 38)

Rating Device	Group		
	Experimental N = 49	Control N = 51	
IQ (Henmon-Nelson Form A)	Range 99-134 M = 112	Range 99-137 M = 116	
Dunning Physics Test Percentiles	Range 12-60 M = 30	End of 11th yr. Range 46-87 M = 63	End of 12th yr. Range 2-70 M = 21
ACS Chemistry Form N, 1958 (Percentiles)	Range 26-98 M = 55	Range 22-98 M = 54	

The above table shows the tests used by Lerner and the results. Lerner did not reach any definite conclusions from the data, but he was confident as a result of talks with students and observations made during the course, that the integrated course was worthwhile.

One of the most extensive programs in secondary school integrated science was carried out by Fiasca (7) in an integrated physics-chemistry course at Portland, Oregon. Fiasca, along with science teachers from Portland, organized a physics-chemistry integrated course to be used in six secondary schools in the Portland area. Fiasca's research yielded the following conclusions:

1. The students in the integrated course showed an increase in critical-thinking abilities developed when compared with students in traditional physics and chemistry courses.
2. In the mastery of physics course content, the integrated course students were significantly superior to the non-integrated students.
3. In the mastery of chemistry course content, there was no significant difference between the two groups.

Fiasca (14) recommended that the integrated course in physics-chemistry be used in other parts of the United States. He also recommended that an analysis be made of such different aspects of critical-thinking, as inference, deduction and evaluation of arguments.

Bull (4) said of the integrated course that the role of science in secondary schools is to bring out the interplay of as many sciences as possible in order to cause the student to understand the physical world. He noted that the colleges have set a precedent in such courses as physical chemistry, biochemistry and geophysics.

In many schools, factors such as space, time and materials are important. These factors dictate the program of instruction and also how it will be implemented. The integrated science course is in essence an answer to the problems created by the previously mentioned factors. Bull also stated that some definite advantages to the integrated course are (4, p. 90):

1. The time gained in classroom hours would be considerable and could be devoted to extending present areas of subject matter on a more advanced level or could be used profitably to coordinate subject matter with life situations.

2. By having a double period for those classes, a greater continuity could be established for the learning situation. Experimentation of a more searching nature could be employed rather than those of "recipe type," which a shorter period encourages.

3. The opportunity for different projects or individual areas of interest would be greater and the teacher could more readily be of assistance to the students in requirements created by individual differences.

4. A better understanding of the difficulties that confront advances in life situations can be had as well as the important role science has in influencing our daily living by recognizing the importance of wise consumption of commodius products.

5. The relationship between chemistry and physics will be more clearly demonstrated to the student to assist in his discovery that the differences between the two subjects are not so great that they should be treated as fields but are really compatible and do much to give a clearer understanding to each other.

Integrated Science Courses in Higher Education

During the past decade, the integrated physics-chemistry course was introduced in several small liberal arts colleges. In 1954, the science faculty at Wabash College proposed a course that would integrate physics and chemistry at the introductory level (25). The course was designed with the following thoughts in mind (25, p. 246):

> Neither modern chemistry nor physics can be understood without knowledge of the other science. Frequently the beginner in chemistry has to take on faith much of the work in atomic structure because he has not the proper background in physics. This difficulty can be avoided in a combined course. Furthermore, much repetition usually found in the customary introductory courses is avoided. This occurs particularly with reference to gas laws, states of matter, atomic structure and electrochemistry.

Haenisch (25) stated that the course at Wabash College was built around the theme of the nature of matter and energy. Topics and the order in which they were treated are as follows (25, p. 246):

I Introduction to Atomic Theory

A. Weight-volume relationships in chemical change
B. Demise of phlogiston theory
C. Arithmetical relations

II Mechanics

A. One dimensional motion
B. Vectors
C. Force
D. Momentum
E. Energy

III States of Aggregation of Bulk Matter

A. Atomic theory
B. Kinetic molecular theory
C. Laws of thermodynamics

IV Electricity and Magnetism

A. Field
B. Electromagnetic radiation
C. Periodic table

V Chemical Bond

A. Chemical reactions
B. Kinetics
C. Oxidation-reduction
D. Electrochemical process

The course was designed for four hours credit per semester with two hours of lecture, one hour of recitation and one three-hour laboratory period per week. It was assumed that the students had the equivalent of four hours of chemistry credit and four hours of physics credit at the end of one academic year.

Haenisch stated that the above course was very well accepted by the students and faculty at Wabash.

In 1961, a conference on integrated physics and chemistry courses was held at Beloit College, Beloit, Wisconsin (20). In attendance were about thirty physicists and chemists from colleges and universities as well as some high school science personnel. The objectives of the conference were as follows (20, p. 6):

1. To discuss the advantages and disadvantages of teaching introductory physics and chemistry together rather than separately.

2. To outline various patterns through which this combination of subject matter may be achieved.

3. To explore ways and means of continuing the development of combined physics-chemistry courses in colleges and in secondary schools.

The prime concern of the participants at the Beloit conference was the organization of the integrated course as it would be taught at the introductory level in college. Most of the discussion was centered about a course that would be for those students planning a major in one of the sciences, but a course for the non-science major also received some discussion.

Several questions evolved from the conference at Beloit. The three most important questions were (21, p. 346):

1. What areas of knowledge usually included in modern introductory physics and chemistry can effectively be combined in an integrated course?

2. Are there pedagogical or philosophical values in having physics and chemistry taught in a combined course?

3. How can the laboratory work be designed in order to make an important contribution to the course?

In answering question one, there seemed to be general agreement on the necessity for inclusion of the following topics (21, p. 346):

Conservation of momentum
Mass-energy
Electric charge
Fields of force
Nature of waves
The particulate nature and structure of matter
The particulate-nature of energy
Chemical change
Constant composition of compounds
Classification of elements, compounds and chemical reactions
Microstructure of simple molecules
Rates of chemical reactions
Chemical equilibrium
Chemical bonding
Nucleonics

A pedagogic advantage was thought to exist in that the integrated course stimulated the faculty to choose carefully the subject matter to be included. This tended to eliminate the so-called "sacred cows," such as: study of groups of elements, the colloidal state, molecular properties of matter and others.

Question three seemed to be virtually solved because the nature of investigation in the laboratory was quite similar regardless of the kind of laboratory, physics or chemistry. An emphasis should be placed on the choice of experiments whereby the concepts studied in the experiments, for example, gas laws, heat and energy exchange and others, would cover both physics and chemistry (21).

At the time of the conference, several colleges and universities were using an integrated course in physics and chemistry. Listed below are some of those that were reported at the conference (20).

	School	Course Title
1.	Beloit College Beloit, Wisconsin	Basic Concepts of Physics and Chemistry
2.	Carleton College Northfield, Minnesota	Chemistry-Physics
3.	Cornell College Mount Vernon, Iowa	Matter and Energy
4.	Denison University Granville, Ohio	A Laboratory-based Course for the Integrated Presentations of the Physical Sciences
5.	Lawrence College Appleton, Wisconsin	Principles of Chemistry Physics
6.	Reed College Portland, Oregon	General Physics; General Chemistry
7.	University of South Florida Tampa, Florida	General Chemistry-Physics

In 1963, Claremont Men's College, Claremont, California, instituted a new science program that included the integration of physics and chemistry in a freshman course (32). This move was prompted by a reorganization within a group of schools in the Claremont area and an attempt to not have a duplication of science programs.

The program at Claremont provided a combined physics-chemistry course in the first semester of the freshman year. The next two semesters would consist of one semester each of physics and chemistry.

The principle reason for the initiation of the program at Claremont was to reduce the duplication of course content material in the first-year chemistry and physics courses. The faculty at Claremont felt that there was at least one semester overlap between the two first-year courses. The integration for one semester should eliminate this duplication. Following the integrated course, a potential science major would take one semester each of physics and chemistry. As a result, the Claremont program had an equivalent of one full year of physics and one full year of chemistry.

Lowry (32) reported that students who have taken the three-semester program at Claremont showed no evidence of a deficiency in basic knowledge in the two disciplines, physics and chemistry.

As a test of the program at Claremont, the students who completed the integrated course and one semester of chemistry were given the <u>ACS Cooperative Examination in General Chemistry</u>. The results on this test showed that the Claremont students compared favorably with the national norms for this test.

Stanitski (41) spoke of the integrated course program at Edinboro State College, Edinboro, Pennsylvania, as it was first used in 1966. The program at Edinboro included the integration of physics and chemistry into a two-semester course. The student was given ten hours credit upon completion of the two-semester course, and he was eligible for upper division work in both physics and chemistry.

The program at Edinboro used team teaching with one physicist and one chemist. Two textbooks were used; they were:

Fundamentals of College Physics

W. E. McCormick

Macmillan, 1965

Chemistry: Principles and Properties

Sienko and Plane

McGraw-Hill, 1966

In the preliminary report of the integrated course at Edinboro an evaluation was not given; however, Stanitski spoke of the integrated course as follows (41, p. 388):

> Since this is a preliminary report, any statements made concerning the overall effectiveness of the program must be guarded ones. At present, the course seems to be meeting the needs for which it was intended. In the future, periodic evaluation will be required to determine whether the course will still be meeting current needs.
>
> Recognizing that local factors such as class size, physical facilities, teaching loads, and scheduling are potential barriers that would make the adoption of the integrated course an impractical choice, nevertheless, schools having the inclination toward or necessity of curriculum revision would be remiss if they did not at least examine the potential of an integrated approach with regard to their needs.

The faculty at Bryn Mawr College gave serious consideration to an integrated course in physics and chemistry in 1954, but it was not until 1962-63 that planning for such a program began to materialize (38).

In the fall of 1963, an integrated course was initiated at Bryn Mawr. This beginning erupted into a full-fledged program which included a grant from NSF for the purpose of preparing a textbook to be used in the course. A preliminary edition of a two-volume work was issued in 1966 (29).

Fuller (19), who was a pioneer in the integrated course program, prepared a questionnaire in May, 1964, concerning the use of integrated physics and chemistry courses in college. The results showed that the number of integrated physics-chemistry courses in colleges in the United States had increased from about twelve in 1961 to about fifty in 1967.

Summary

The research that has been published on integrated physics-chemistry courses in both secondary schools and colleges can be summarized as follows:

1. There is a considerable savings of time due to the reduction of subject matter duplication (4).
2. There is a greater provision for the understanding of each of the disciplines by studying the other (4).

3. The integrated course gives the student a much broader appreciation of the physical sciences, thereby giving him a better basis for a choice of a major field of study (21).
4. The majority of the integrated courses in physics and chemistry are designed primarily for science majors (19).
5. During the past seven years there has been a fourfold increase in the number of integrated physics-chemistry courses in the United States (19).
6. One should expect the students from the integrated course to develop critical-thinking abilities at a faster rate than the students in the traditional science courses (14).
7. The studies on integrated courses are limited in that there is only one published study (14).
8. A definite need is apparent for the constant evaluation of the integrated courses.
9. New textbooks are in the process of being written and refined for integrated courses (29).
10. The schools that have reported on the integrated course indicated that the program was successful (14, 25, 30).

Chapter III

THE STUDY

Population Groups

Several colleges were contacted about participating in the research program as described in this study. They were as follows:

Baker University Baldwin, Kansas	A Methodist liberal arts college of about 1000 students
Central Methodist College Fayette, Missouri	A Methodist liberal arts college of about 930 students
Graceland College Lamoni, Iowa	A liberal arts college of about 1100 students associated with the Reorganized Church of Jesus Christ of Latter Day Saints
Kalamazoo College Kalamazoo, Michigan	A Baptist liberal arts college of about 1200 students
McPherson College McPherson, Kansas	A liberal arts college of about 750 students associated with the Church of the Brethren
Sterling College Sterling, Kansas	A liberal arts college of about 600 students associated with the United Presbyterian Church
Tarkio College Tarkio, Missouri	A liberal arts college of about 800 students associated with the United Presbyterian Church
William Jewell College Liberty, Missouri	A Baptist liberal arts college of about 1000 students

William Penn College Oskaloosa, Iowa	A Quaker liberal arts college of about 850 students
Wilmington College Wilmington, Ohio	A Quaker liberal arts college of about 850 students

The above schools were considered for this study based on the following criteria:

1. Size
2. Location
3. Religious affiliation
4. Basic objectives
5. Entrance requirements
6. They had a course in general chemistry or a course in integrated physics-chemistry.

At the beginning of this research study, the following colleges agreed to participate in this program:

<u>Control Group</u> (conventional chemistry course)

Central Methodist College	Fayette, Missouri
Sterling College	Sterling, Kansas
William Jewell College	Liberty, Missouri
William Penn College	Oskaloosa, Iowa
Wilmington College	Wilmington, Ohio
McPherson College	McPherson, Kansas

<u>Experimental Group</u> (integrated physics-chemistry course)

Kalamazoo College	Kalamazoo, Michigan

Tarkio College	Tarkio, Missouri

The above named schools provided population totals of:

Control Group	140 students
Experimental Group	173 students

These figures for the population groups were used in the original thesis proposal and were a part of the original plan for the research study.

Following the final semester of the academic year in which the study was conducted, results of the examinations were received from only four colleges. They were as follows:

Control Group	Experimental Group
Central Methodist College	Tarkio College
McPherson College	
William Penn College	

The failure of some of the schools to give the examinations and report the results caused the population totals to be reduced to the following:

Control Group	94 students
Experimental Group	83 students

When contacted, the schools indicated their inability to give the examination for a variety of reasons.

The compromises that were made as a result of the withdrawal of part of the population limited the scope of this research study. As a result, some of the generalizations that could ordinarily have been made about the original proposal cannot be made in this study. For example, the results of the data analysis would be less able to be extended to all liberal arts colleges owing to the limited population employed. The limiting factor is the experimental group where only one college was represented.

In order to effectively compare the population groups (experimental and control) on the results of the examinations, one must assume the populations as being normal and equal in ability prior to entering the program. A method of obtaining knowledge of equality or inequality is to give a pre-test or obtain information about the students. Such information could include high school grade-point average in science courses, science courses taken in high school, pre-college test scores or other criteria that will indicate the ability of the student.

Due to the time element, the pre-test was not given. An attempt was made to obtain grades and test information from the participating schools but the files on the students were not open to this investigator. Most colleges are very reluctant to open their files to persons outside their schools.

Owing to the absence of prior information on the students in the population groups, an experimental design was chosen that uses only a post-test. This design is described in the next section.

In addition to the variable attributed to student differences, another variable relative to the instructors could also have been present. An analysis of the instructors in the program shows that they have nearly the same type of background in education and teaching positions. The possible differences in the instructional program attributed to the instructors is not believed to be an important factor.

Experimental Design

The experimental design used in this study is similar to that described in Gage (22, p. 195) and is commonly called "The Post-test Only Control Group Design." This design has the following form:

$$\begin{array}{ccc} R_1 & X & O_1 O_2 \\ R_2 & & O_1 O_2 \end{array}$$

R_1 represents the group of students in the integrated physics-chemistry course.

R_2 represents the group of students in the conventional chemistry course.

X represents the variable, which is the different approach to teaching chemistry.

O_1 represents the test on critical-thinking ability. Watson-Glaser Critical-Thinking Appraisal, Form Ym.

O_2 represents selected items from the chemistry test. ACS Cooperative Examination in General Chemistry, Form 1965.

This type of design although not used extensively in psychological and education research, has validity within the limits of confidence as stated by the test of significance.

Campbell and Stanley (22) stated that the pretest post-test design was most often used, owing to the misconception of experimenters that equality can only be achieved by the pretest. The post-test-only design had been used as long ago as 1920 but had not received extensive support in tests on methodology in education.

Description of Courses

Control Group

The following are catalog descriptions and textbooks used in the chemistry courses in the control group:

Central Methodist College Bulletin, Fayette, Missouri (6, p. 96)

111. General Chemistry I. 4 hours. Three hours lecture, 2 hours laboratory. An introduction to General Chemistry and Elementary Physical Chemistry, including atomic structure, periodic table, equilibrium, reactions and properties of elements and compounds, solutions and electrochemistry. Prerequisite; adequate background in high school Chemistry or Chemistry 100.

112. General Chemistry II. 4 hours. Three hours lecture, two hours laboratory. A continuation of Chemistry 111. Prerequisite, Chemistry 111.

Textbook General College Chemistry
Kennan and Wood
3rd Edition
Harper and Row

McPherson College Bulletin, McPherson, Kansas (34, p. 62):

1. General College Chemistry

   A study of the fundamental principles of chemistry, the properties of matter and what changes it may undergo. Some historical background is presented along with an emphasis on the importance of chemistry to our modern world. Class session three hours, laboratory two hours.

Fall (10:30 T. Th. F., laboratory 1:15-3:00 T., W. or 3:05-4:55 T.)

12. Inorganic Chemistry and Qualitative Analysis

A study of the chemistry of the metals and non-metals; laboratory work in qualitative analysis. Class session three hours, laboratory six hours. Prerequisite: Chemistry 1. Spring (10:30 T. Th. F.), laboratory meeting period (1:15-2:05 T.)

Textbook — College Chemistry
King and Caldwell
4th Edition
American Book Company

William Penn College Bulletin, Oskaloosa, Iowa (46, p. 62):

101. College Chemistry

A study of selected principles, theories, laws and applications of chemistry as means of understanding common experiences of a chemical nature. Exploratory, descriptive, and experimental study of the behavior and interaction of the more common chemical substances. Prerequisite: One year of high school chemistry and a passing grade in a placement exam or a grade of "C" in 105a Fundamentals of Chemistry I, Mathematics 103 which can be taken simultaneously with the course. Two lectures, one drill section and one three-hour laboratory period per week. Four hours credit.

102. General Chemistry and Qualitative Analysis

A continuation of the study of General Chemistry principles with 101 as a prerequisite. Much of the laboratory and some of the lecture time to be taken with separation and analysis of cations and identification of anions with study of metals and equilibria. Two lectures, one drill session and one three-hour laboratory period per week. Four hours credit.

Textbook

<u>Chemistry</u>
Sienko and Plane
3rd Edition
McGraw-Hill

<u>Experimental Group</u>

The following is a catalog description of the experimental course. (Integrated physics-chemistry)

<u>Tarkio College Bulletin</u>, Tarkio, Missouri (42, p. 52):

101. Science I (4)

> A course introducing basic principles of chemistry and physics. This course will blend the fundamental concepts of the two disciplines. Three lectures and one three-hour laboratory. Prerequisite: Eligibility for enrollment in 14:100 Basic Mathematics.

102. Science II (4)

> Continuation of 10:101. Three lectures and one three-hour laboratory. Prerequisite: 10:101.

Textbooks

<u>Chemistry</u>
Sienko and Plane
3rd Edition
McGraw-Hill

<u>College Physics</u>
Weber, White and Manning
4th Edition
McGraw-Hill

A better design for this research study may have included students in a physics course so as to obtain a comparison between the integrated course and a physics course. This was not done for two reasons.

1. There is an absence of classes of adequate size in physics.

2. There is an absence of an adequate test to measure achievement in physics.

The first obstacle could have been handled by contacting a large number of schools for the study. This did not seem feasible in view of the wide variety of courses, instructors and textbooks that are used. The second obstacle was not so easily solved as the time of this research study, an adequate test in physics did not exist. This investigator made several inquiries concerning such tests including the following people or organizations.

1. American Association of Physics Teachers
2. Psychometric Department, Oregon State University
3. Physics Department, Oregon State University
4. Educational Testing Service

This inquiry concerning physics tests did not yield a test that could be used in this type of study. The test would have to be of a type similar to the ACS test. Personnel at the Psychometric Department indicated that such a test was not available.

Selection and Description of Tests

Chemistry Test

Since the only area of course content used was chemistry, the measurement of achievement in chemistry was determined by the administration of the ACS Cooperative Examination in General Chemistry, Form 1965.

The 1960 and 1963 forms of this test have been reviewed and discussed in Buros (5) and the concensus of the reviewers was that these forms are adequate in measuring the achievement in general chemistry. The 1965 edition has not been reviewed as yet, but statistical and percentile tables indicate that this form is on a par with other forms of the test.

The test is divided into two parts. Part I contains 52 questions with five choices for the answer. The questions in Part I are of the type that require very little calculation and require mostly recall of facts and interpretations of concepts. Part II contains 28 questions with five choices for the answer. The questions in Part II are primarily of a problem nature, requiring calculation.

Examples of the types of questions found in Parts I and II are:

Part I

34. Which of the following exhibits non-polar bonds?

(a) CCl_4

(b) CO_2

(c) H_2O

(d) O_2

(e) none of these

Answer Sheet

	a	b	c	d	e
34.	||	||	||	||	||

Part II

72. Balance the following reaction.

$$\underline{\quad\quad} MnO_2 + \underline{\ \ ?\ \ } HCl \rightarrow Mn^{++} + \underline{\ \ ?\ \ } Cl^{-} + Cl_2 + \underline{\ \ ?\ \ } H_2O$$

The coefficient of HCl is

(a) 1 (d) 2

(b) 4 (e) 8

(c) 3

Answer Sheet

	a	b	c	d	e
72.	||	||	||	||	||

The student was given the test at one sitting with time restrictions as follows:

Part I - 50 minutes

Part II - 55 minutes

Part III - 105 minutes

Reviewers in Buros (5), the 1963 edition, indicated that the time period in which the student had to complete the test was adequate.

The test is designed to adequately test a student having had one academic year of general chemistry. The test has been proven reliable as indicated by the Kuder-Richardson Reliability Coefficient.

Part I	Part II	Total
r = 0.898	0.800	0.918

r = Kuder-Richardson Reliability Coefficient found from formula No. 21.

Owing to the fact that the students in the integrated course had not been exposed to as much chemistry content as those in the chemistry course, selected items from the above mentioned test were chosen by the investigator and two members of the Tarkio College chemistry staff as being representative of those topics covered in the syllabus in the experimental course. (See Appendix D) The selected items numbered 47. These items comprised the test this investigator labelled ACS II.

In order to get as complete data as possible from this test, the complete test was used and labelled ACS I.

This investigator and two members of the Tarkio College chemistry staff also selected from the 80 questions in the test, those questions that have overtones of physics attached to them. These questions cover such topics as: atomic structure, electrochemistry, gas laws, and heat exchange. The questions in this group were labelled ACS III.

<u>Summary of ACS Tests</u>

ACS I	-	Total ACS Test
ACS II	-	Selected items covered in integrated course syllabus
ACS III	-	Questions with physics content
ACS IV	-	Questions totally relating to chemistry

Critical Thinking Abilities

The second test used in this study was the Watson-Glaser.

Critical-Thinking Appraisal, Form Ym. (CTA)

This investigator chose this test on the basis of the objectives outlined by the authors (44). The authors seek to provide an estimate of the student's standing in a composite of abilities such as attitudes, knowledge and skills. Watson and Glaser (44) stated (44, p. 10):

> This composite includes: (1) attitudes of inquiry that involve an ability to recognize the existence of problems and an acceptance of the general need for evidence in support of what is asserted to be true; (2) knowledge of the nature of valid inferences, abstractions, and generalizations in which the weight or accuracy of different kinds of evidence are logically determined; and (3) skills in employing and applying the above attitudes and knowledge.

Hovland (27) indicated that this measurement tool is useful in evaluating programs of instruction. He also states that this use of CTA is receiving additional importance in view of present day emphasis on improving instruction in scientific reasoning.

The CTA consists of five sub-tests with titles as follows:

1. Inference (20 items)
2. Recognition of Assumptions (16 items)
3. Deduction (25 items)
4. Interpretation (24 items)
5. Evaluation of Arguments (15 items)

The CTA is a 100 question, multiple choice test having a time limit of 50 minutes.

In the first sub-test, the student is asked to read a prepared statement consisting of certain facts. Each item of the sub-test contains an inference. The student is asked to determine the degree of truth or falsity. The choices the student has on the inference are:

T	-	true	ID	-	insufficient data
PT	-	probably true	PF	-	probably false
			F	-	false

The second sub-test consists of a statement and proposed assumptions based on a statement. The student is asked whether the assumption is "made" or "not made" in the statement.

The third sub-test consists of a statement followed by some conclusions. The student is asked whether the conclusion "follows" or "does not follow" according to the original statement.

The fourth sub-test provides a paragraph followed by several conclusions. The student is asked to interpret the conclusions as to whether they "follow" or "do not follow" according to the original paragraph.

The fifth sub-test asks the student to evaluate an argument as it refers to a statement. The arguments are to be classified as "strong" or "weak".

Although it may be reasonable to assume that a close correlation exists between critical-thinking skills and intelligence, Reilly (37) indicated that this correlation is actually only around 0.45. Reilly, in his paper, also related the need of a critical-thinking test as opposed to an intelligence test as the intelligence test does not measure critical-thinking skills. This observation was also made by Watson (44). Reilly also stated that it should be clear that the classroom teacher is a critical factor when it comes to the development and the evaluation of critical-thinking abilities. The essence of the last statement is, if the instructor wants his students to draw inferences from statements or laws of science, he must encourage such actions and not just assume that the good student has this ability.

Collection of Data

The tests described above were administered to the population groups at the close of the academic year 1966-67. The tests were administered by the instructors and assistants at the respective schools. The grading was done by the same instructors and assistants. The results of the tests given to the total population were collated by this investigator.

Statistical Treatment

The type of experimental design employed in this study is the post-test only design and the recommended statistical significance test is the t-statistic (45).

The basic hypotheses of each test given are:

$$\bar{X}_A = \bar{X}_B \qquad \text{and} \qquad S_A^{\,2} \neq S_B^{\,2}$$

where $\bar{X}_A$ and $S_A^{\,2}$ represent the mean and the variance of the experimental group and $\bar{X}_B$ and $S_B^{\,2}$ represent the mean and the variance of the control group.

The t-statistic is calculated by:

$$t = \frac{\bar{X}_B - \bar{X}_A}{\sqrt{\dfrac{S_A^{\,2}}{N_A} + \dfrac{S_B^{\,2}}{N_B}}}$$

The statistical equations are valid to use for calculating the t-statistic with the basic hypothesis mentioned above. Yamane (47) indicated that this procedure of calculating the t-statistic is valid whether the distributions are normal or not.

The data to be examined are the results of the ACS test and the CTA test. The ACS test was subdivided into four tests. The CTA test was examined in total.

The means of each of the ACS tests for the experimental and control groups were determined by statistical treatment using the

1130 IBM computer. Each set of means was examined by comparing the differences using the t-statistic.

This procedure was also employed on the difference between the means of the CTA test.

Summary

This study was carried out with the basic experimental design, "post-test only design", using the t-statistic as the significance test.

The population groups consisted of a control group and an experimental group. The control group was comprised of 94 students from three colleges who were enrolled in a general chemistry course. The experimental group was comprised of 83 students from one college who were enrolled in an integrated physics-chemistry course.

The population groups were treated with two basic tests, ACS Cooperative Test in General Chemistry, Form 1965, and Watson-Glaswer Critical-Thinking Appraisal, Form Ym. The ACS test was divided into four sub-tests in order to get a more meaningful measure of course content in chemistry.

Chapter IV

ANALYSIS OF DATA

Population Groups

The population groups used in this study were chosen from four liberal arts colleges. The control group consisted of students who were enrolled in a conventional first-year college chemistry course. The experimental group consisted of students who were enrolled in an integrated course in physics and chemistry. Table I shows the distribution of the students in the population groups. It is estimated that about 80% of the total population were freshmen.

Table I. Population Groups.

	Population Group	
College	Control	Experimental
Central College Fayette, Missouri	47	
McPherson College McPherson, Kansas	21	
Tarkio College Tarkio, Missouri		83
William Penn College Oskaloosa, Iowa	26	
Totals	94	83

Statistical Methods

The data from the tests given were analyzed using an IBM 1130 computer. The following statistical measurements were found from each set of scores from the population groups.

$\bar{X}$	-	mean
X_{med}	-	median
s^2	-	variance
σ	-	standard deviation
t	-	t-statistic
X_H	-	high score
X_L	-	low score

The above statistical measurements are listed in tables in this chapter.

Critical-Thinking Appraisal

Table II shows that the different between the means of the CTA is 5.7 in favor of the control group. This difference in the means shows a t-statistic of 4.32. An inspection of a t-distribution (35) for a two-tailed test, shows that this value is significant at both the 0.05 and 0.01 levels of significance.

Hypothesis number one states that there is no difference between the means of the population groups. The level of significance being set at the 0.05 level shows that this hypothesis is untenable.

Table II. Statistical Measurements for the Watson-Glaser Critical-Thinking Appraisal (100 Items).

Measurement	Population Group	
	Control	Experimental
$\bar{X}$	75.4	69.7
X_{med}	75.2	68.5
s^2	68.2	80.6
σ	8.26	8.98
X_H	91	89
X_L	51	45

The data in Table II shows the control group to be superior in the measurements used to analyze the CTA test. Watson and Glaser (44) reported on this test as it was given to 5,297 freshmen from liberal arts colleges. The data obtained showed the mean to be 70.2 and the standard deviation to be 9.8. The range of scores was given as 19-95. The population groups used in this study compare favorably with this group as reported by Watson and Glaser.

The range of scores made by the control group showed that the low score, X_L, was 2.95 standard deviations below the mean. This number is given as the standard score and is defined as (45):

$$\text{standard score} = \frac{X - \bar{X}}{\sigma}$$

$$(X_L) \quad \text{standard score} = \frac{-24.4}{8.26}$$

$$(X_L) \quad \text{standard score} = -2.95$$

The standard score of X_H, the high score, for the control group was found to be 1.89.

$$(X_H) \quad \text{standard score} = \frac{+15.6}{8.26}$$

$$(X_H) \quad \text{standard score} = +1.89$$

Figure 1 shows the distribution of scores by the control group on the CTA. The curve shows a skewness to the left.

An analysis of the scores of the experimental group on the CTA yields the following standard scores:

$$(X_L) \quad \text{standard score} = \frac{-24.7}{8.98} \quad \text{or } -2.75$$

$$(X_H) \quad \text{standard score} = \frac{+19.3}{8.98} \quad \text{or } +2.15$$

Figure 2 shows the distribution of scores by the experimental group on the CTA. This curve shows a tendency toward a bimodal distribution.

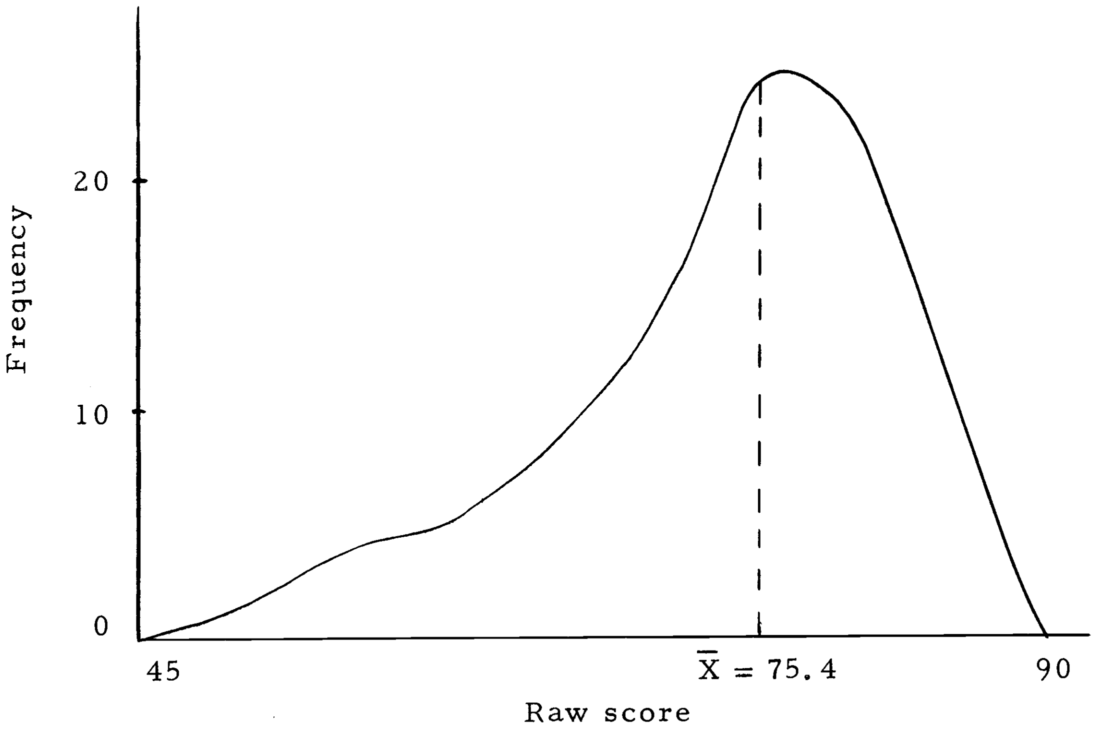

Figure 1. Distribution of scores of control group on the Watson-Glaser Critical Thinking Appraisal.

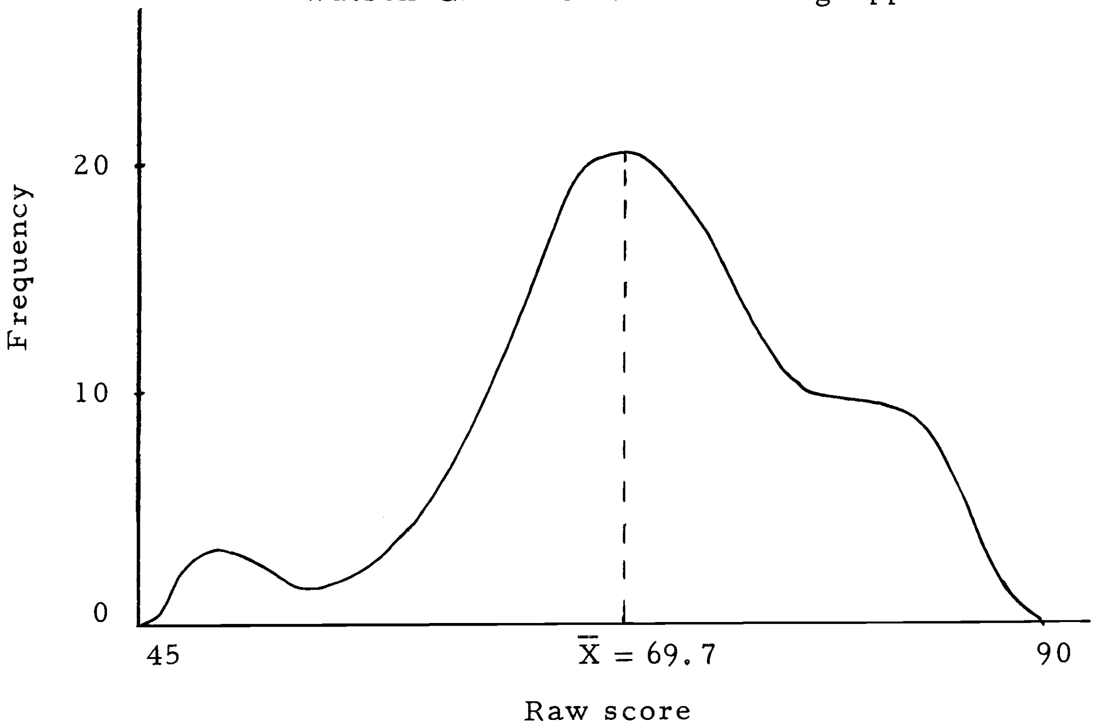

Figure 2. Distribution of scores of experimental group on the Watson-Glaser Critical Thinking Appraisal.

Chemistry Content

As indicated in Chapter I of this study, the ACS Cooperative Examination in General Chemistry, Form 1965, was used to measure the achievements in chemistry content of the population groups.

The ACS test is considered by the publisher to be confidential material as the test is used extensively each year throughout the United States. As a result, the test was not duplicated in this study.

Because the control group was exposed to more chemistry than physics during the course of the two terms, this investigator and two members of the chemistry department of Tarkio College, Tarkio, Missouri, made a survey of the ACS test and divided it into four subtests. They are as follows:

ACS I - This test includes the total ACS test.

ACS II - This test includes items that were germaine to the experimental course. (See experimental course syllabus in Appendix D)

This test has 47 items as follows: (Item numbers are as they appear in the ACS test)

(47 items) 1, 2, 3, 5, 6, 7, 8, 9, 10, 12, 13, 15, 16, 17, 19, 20, 22, 26, 32, 35, 36, 39, 40, 43, 44, 45, 47, 51, 53, 54, 55, 56, 57, 58, 59, 62, 64, 65, 66, 67, 68, 69, 70, 72, 74, 75, 78

ACS III - This test includes those items from the ACS test that have an obvious relationship to concepts of physics.

This test has 21 items as follows:

(21 items) 1, 2, 3, 8, 15, 17, 19, 26, 43, 44, 45, 46, 56, 57, 58, 59, 60, 61, 68, 73, 76

ACS IV - This test includes items from the ACS test that were considered chemistry questions only. This test includes all questions on the total test less those questions on ACS III. There are 59 items.

Table III shows the statistical data obtained from the ACS I test. The data clearly shows that the control group was superior on this test by a considerable margin. This was due to the inclusion of all of the questions in this test. This investigator estimated that the control class was able to spend about 30% more time on matters pertaining to chemistry than the experimental group. The difference between the means is 7.2 and the t-ratio is 6.21.

The high and low scores on this test also give some indication of the achievement of the students in the two groups.

An analysis of the results of this test using the t-statistic to compare the difference between the means shows that this value of the t-ratio is significant at both the 0.05 and 0.01 levels of confidence.

Table III. Statistical Measurements for the ACS I Test, All Questions on the ACS Cooperative Examination in General Chemistry (80 Items).

	Population Group	
Measurement	Control	Experimental
$\overline{X}$	23.3	16.1
X_{med}	20.1	14.6
s^2	42.6	75.7
σ	6.53	8.70
X_H	47	35
X_L	7	2

Hypothesis number two states that there is no difference between the means of this test. At the 0.05 level of significance, this hypothesis is untenable.

Figures 3 and 4 show the distribution of scores on ACS I by the control and experimental groups.

The graphs in Figures 3 and 4 are both skewed to the right. Close inspection shows the scores on the experimental group are closely grouped around the mean.

The standard scores range from -2.50 to +3.64 for the control group, and -1.62 to +2.18 for the experimental group. An analysis of these standard scores will show the nature of the curves in Figures 3 and 4.

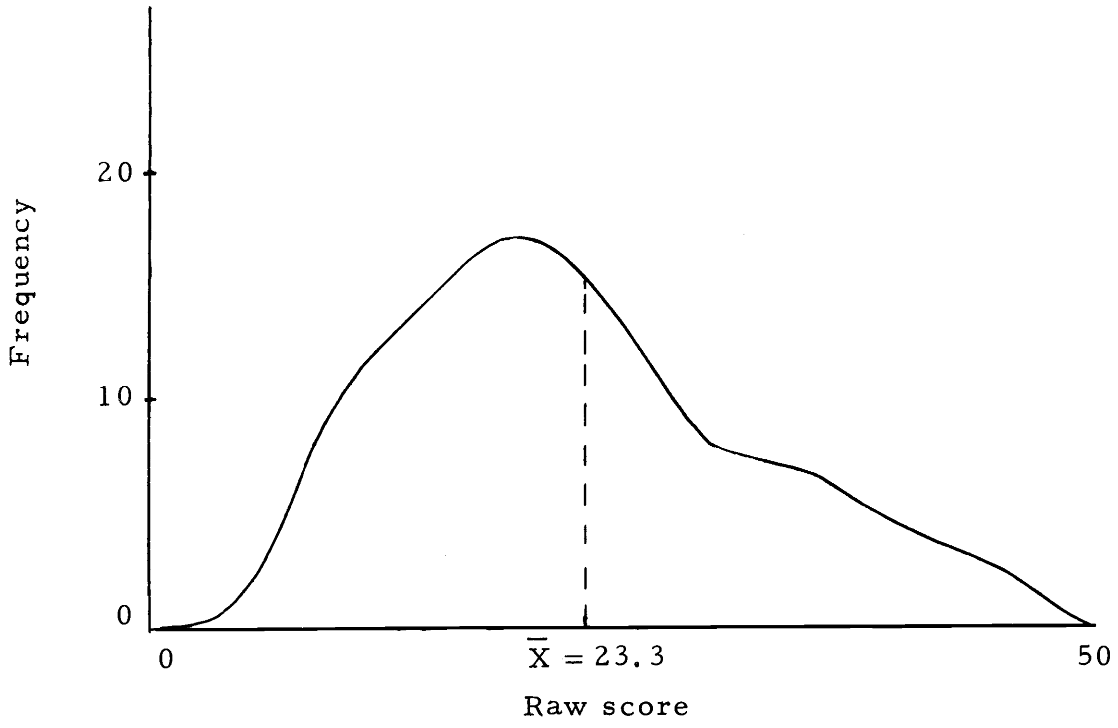

Figure 3. Distribution of scores by control group on ACS I test.

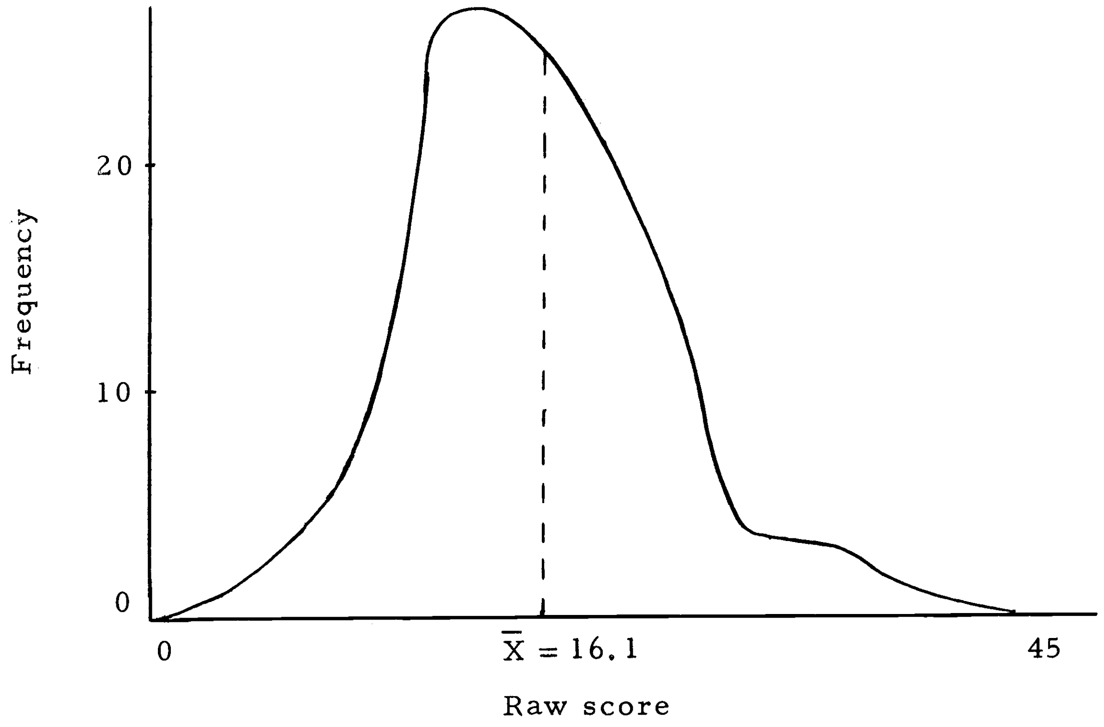

Figure 4. Distribution of scores by experimental group on ACS I test.

Table IV shows the statistical measurements from ACS II, questions from the ACS Cooperative Examination in General Chemistry, Form 1965, relating to the experimental course.

Table IV. Statistical Measurement for ACS II, Questions From ACS I Related to the Experimental Course (47 Items).

Measurement	Population Group	
	Control	Experimental
$\bar{X}$	15.4	11.9
X_{med}	14.3	9.75
s^2	31.4	30.6
σ	5.60	5.53
X_H	31	25
X_L	4	1

The results of this test show that the control group has an edge in the measurements but it is not as significant as in ACS I. The difference in the means is only 3.5. Since this test was selected with the idea of equating the two population groups to the amount of exposure to chemistry, the statistical measurements are expected to show closer results on the scores. An analysis of the difference between the means using the t-statistic shows a t-ratio of 4.11. Hypothesis number three, which states that there is no difference between the means, is untenable at the 0.05 level of significance.

Figures 5 and 6 show the distribution of scores by the control and experimental groups on the ACS II test. In Figure 5, one sees a definite bimodal distribution at an area near the mean.

Table V. Statistical Measurements for ACS III, Questions From ACS I Containing Physics Concepts (21 Items).

Measurement	Population Group	
	Control	Experimental
$\bar{X}$	6.33	4.88
X_{med}	5.62	4.25
s^2	7.32	6.30
σ	2.69	2.51
X_H	13	11
X_L	1	0

An inspection of the measurements on Table V shows the control group has exceeded the experimental group in all phases of central measurement. The margin is not as large as it was on the other tests in this study. An analysis of the difference between the means using the t-statistic shows a t-ratio of 3.70.

Hypothesis number four states that there is no difference between the means on the ACS III test. This difference, 1.45, is

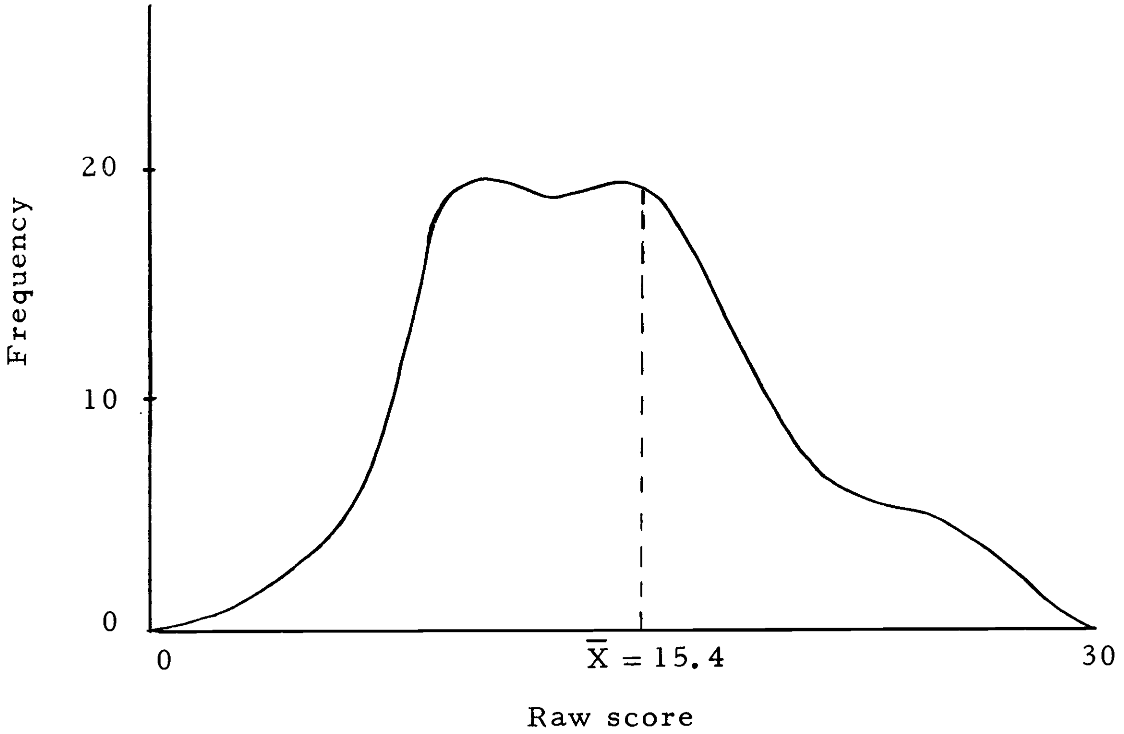

Figure 5. Distribution of scores by control group on ACS II test.

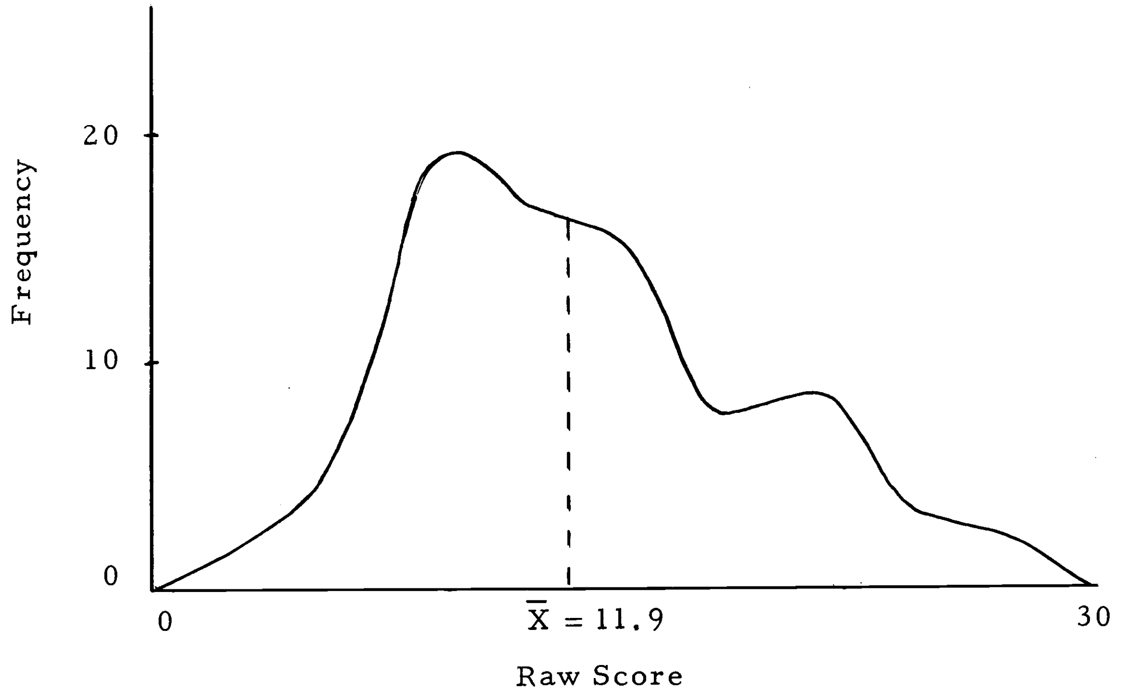

Figure 6. Distribution of scores by experimental group on ACS II test.

significant at the 0.05 level of confidence. With this value of the t-ratio, hypothesis number four is untenable at the 0.05 level of significance.

Figures 7 and 8 show the distributions of scores by the population groups on the ACS III test. The distribution as seen in Figure 7 shows a near normal distribution with a slight deviation to the right of the mean. An analysis of the standard scores shows that they range from -1.98 to +2.51 standard deviation units below and above the means.

Table VI. Statistical Measurements for the ACS IV Test (Questions on ACS I less Those on ACS III).

	Population Group	
Measurement	Control	Experimental
$\overline{X}$	16.9	11.4
X_{med}	14.5	10.6
s^2	44.9	23.6
σ	6.70	4.85
X_H	36	26
X_L	6	3

Although the measures of central tendency show marked differences between the two test distributions, when one observes the

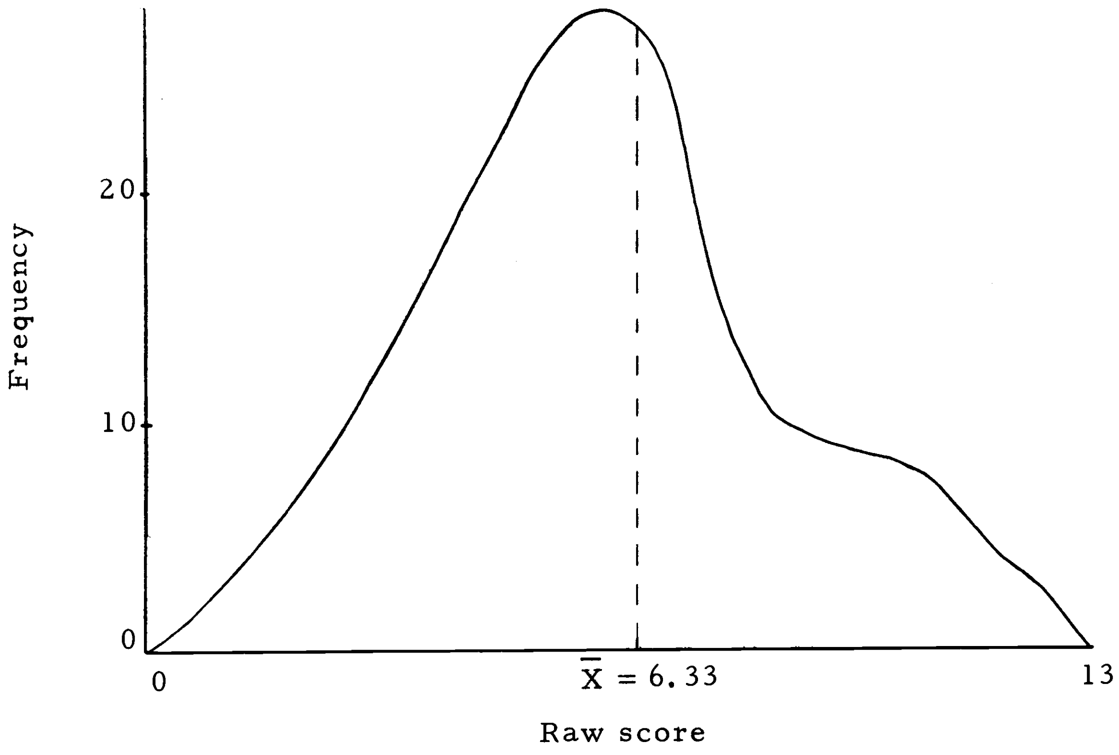

Figure 7. Distribution of scores by control group on ACS III test.

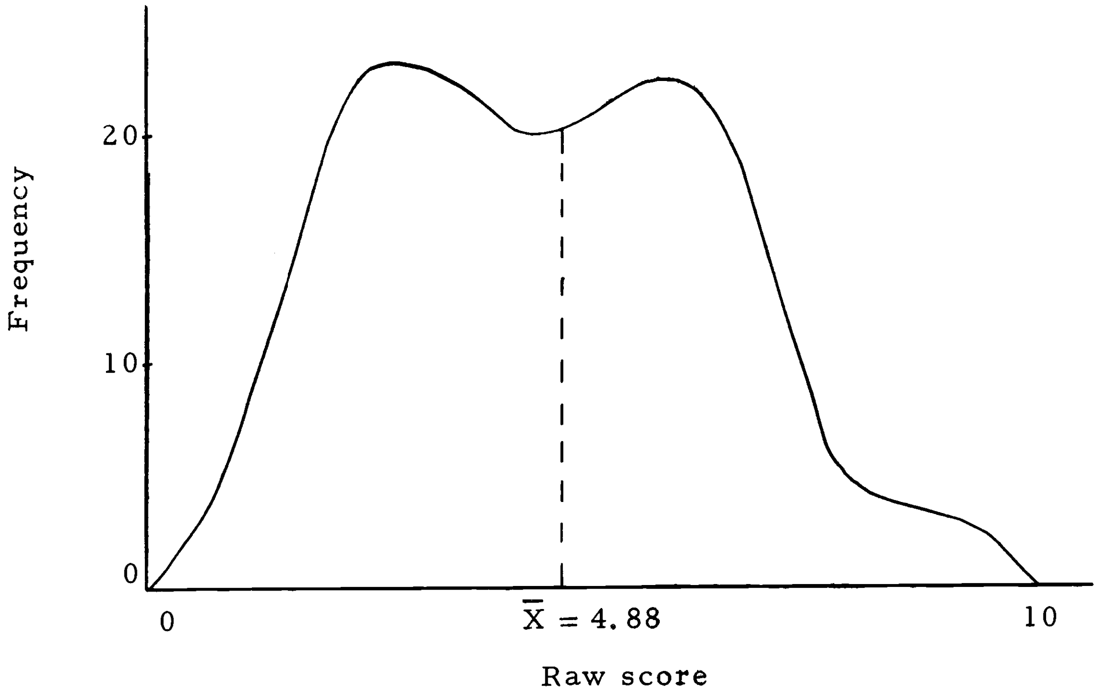

Figure 8. Distribution of scores by experimental group on ACS III test.

distributions in the curves (Figures 7 and 8) their differences do not seem so obvious.

Table VI shows the measurements achieved by the population groups on the ACS IV test. The measurements clearly show that the control group is superior in each statistic employed. The difference between the means is 5.4 and by employing the t-statistic, the t-ratio for this difference is 6.28. At the 0.05 level of significance, this value is significant.

Hypothesis number five states that there is no difference between the means on this test and at the above mentioned level of significance, this hypothesis is untenable.

Figures 9 and 10 show the distribution of scores on the ACS IV test. It is clear from the nature of the curves that the control group has a considerable margin in the measures of central tendency.

The curve in Figure 10 shows a large grouping of scores around the mean of 11.4. The curve in Figure 9 shows a distribution similar to a normal distribution. The standard scores in Figure 9 range from -1.63 to +2.86 standard deviation units below and above the mean.

Summary

Table VII shows the summary of the statistical analysis for all tests. In each case the difference between the means was significant

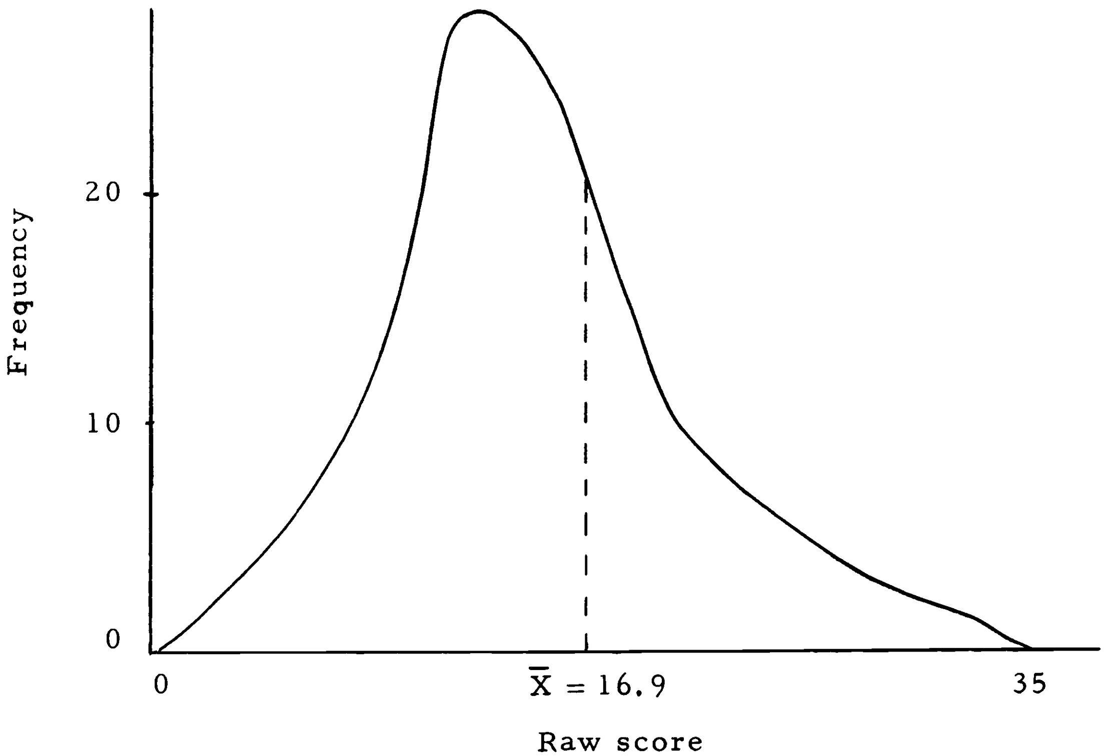

Figure 9. Distribution of scores by control group on ACS IV test.

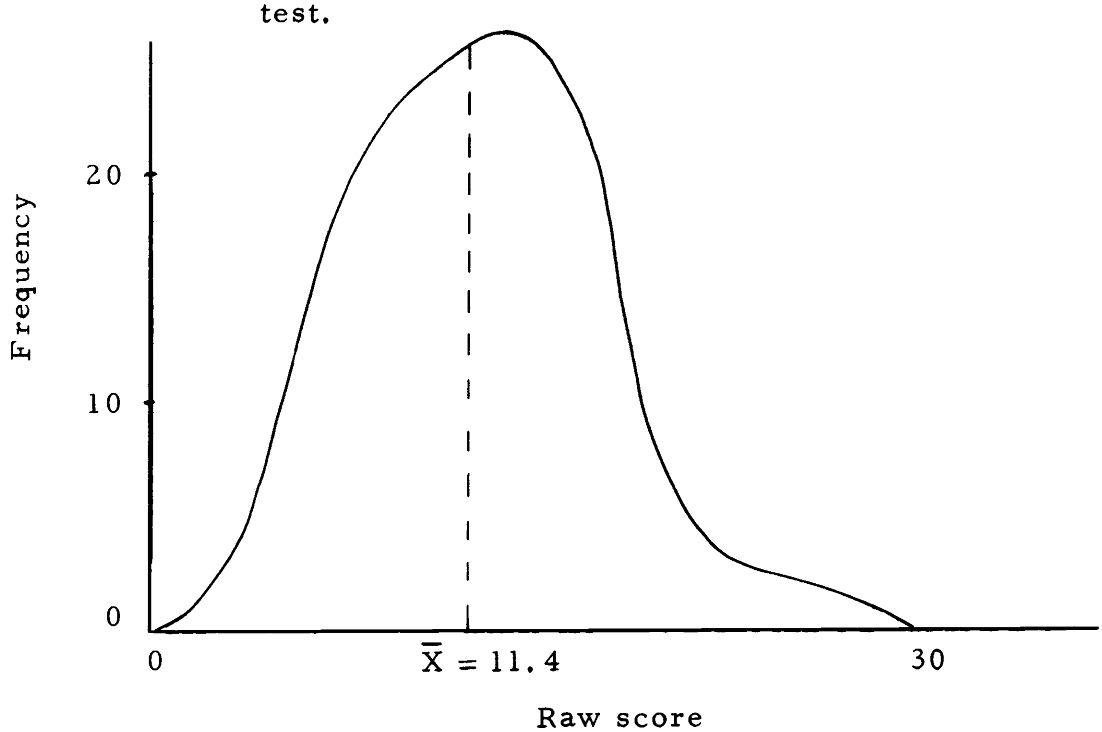

Figure 10. Distribution of scores by experimental group on the ACS IV test.

at the 0.05 levels.

Table VII. Summary of the Statistical Analysis on All Tests.

Test	Mean		Diff. in Means	t-ratio
	Con.	Exp.	$\bar{X}_{con.} - \bar{X}_{exp.}$	
CTA (100 items)	75.4	69.7	+5.7	4.32*
ACS I (80 items)	23.3	16.1	+7.2	6.21*
ACS II (47 items)	15.4	11.9	+3.5	4.11*
ACS III (21 items)	6.3	4.9	+1.4	3.70*
ACS IV (59 items)	16.9	11.4	+5.4	6.28*

*Significant at the 0.05 level.

Chapter V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

Purpose of the Study

There are about 50 colleges in the United States that have an integrated physics-chemistry course in their curriculum. The following colleges were among the first to attempt this type of program.

Bryn Mawr College	Bryn Mawr, Pennsylvania
Beloit College	Beloit, Wisconsin
Reed College	Portland, Oregon
Wabash College	Crawfordsville, Indiana

Because there are so many schools using this type of course and because of the possibility of more schools adopting it in the near future, this investigator believed that a study was needed in order to evaluate such a program in a liberal arts college.

The purpose of this study is to compare the mastery of subject matter studied and critical-thinking abilities developed between students who studied chemistry in a conventional course and students who studied chemistry in an integrated physics-chemistry course.

More specifically, the following questions were involved in this study:

1. To what extent do students who study in a conventional chemistry course differ in course content mastered from students who study in an integrated physics-chemistry course?

2. To what extent do these same two groups differ in the development of critical-thinking abilities?

Population Groups

The population groups consist of a control group, 94 students from three liberal arts colleges, and an experimental group, 83 students from one liberal arts college. The control group consists of students enrolled in a general chemistry course, and the experimental group consists of students enrolled in an integrated course in physics and chemistry. Both groups studied for a period of one academic year.

Hypotheses

The hypotheses of this study are stated in null form as follows:

1. There is no difference in the critical-thinking abilities between the control group and the experimental group.

Hypotheses two through five are of the same form but represent different tests used to measure different aspects of achievement in chemistry.

2. There is no difference in the achievement in chemistry as

measured with the ACS I test, between the control group and the experimental group.

3. There is no difference in the achievement in chemistry as measured with the ACS II test, between the control group and the experimental group.

4. There is no difference in the achievement in chemistry as measured with the ACS III test, between the control group and the experimental group.

5. There is no difference in the achievement in chemistry as measured with the ACS IV test, between the control group and the experimental group.

Tests Used

The test used to measure the achievement in critical-thinking abilities is the *Watson-Glaser Critical Thinking Appraisal, Form Ym*.

The tests used to measure chemistry achievement as indicated in hypotheses two through five are:

ACS I - *ACS Cooperative Test in General Chemistry, Form 1965*

ACS II - Selected items from ACS I (physics-chemistry emphasis)

ACS III - Selected items from ACS I (physics emphasis)

ACS IV - Selected items from ACS I (chemistry emphasis)

Experimental Program

The experimental program was designed to give the students in the integrated course two terms of the fundamental and basic concepts of physics and chemistry. At the end of this two-semester course, the students were given the battery of tests listed above.

The same battery of tests was given to the control group and the results of the two groups of tests were analyzed.

Conclusions

There are five hypotheses presented in Chapter I of this study and again in Chapter V (p. 61-62). Within the assumptions (p. 10-11 and limitations (p. 11), the following conclusions are made:

1. There is a significant difference (at the five percent level) in the critical-thinking abilities between the group of students that studied in the conventional chemistry course (control group) and the group of students that studied in the physics-chemistry course (experimental group) in favor of the control group.
2. There is a significant difference (at the five percent level) in the achievement in chemistry content between the group of students that studied in the conventional course (control

group) and the group of students that studied in the physics-chemistry course (experimental group) in favor of the control group.

3. Hypothesis number one stated in null form is as follows: There is no difference in critical thinking abilities between the control group and the experimental group. This hypothesis is untenable and is rejected as a result of the statistical findings as reported in Chapter IV of this study.

4. Hypotheses two through five are of the same form but refer to different tests. The general form stated in null form is as follows: There is no difference in the achievement in chemistry as measured with the ACS test and subtests, between the control group and the experimental group. These hypotheses are untenable and are rejected as a result of the statistical findings as reported in Chapter IV of this study.

5. An integrated physics-chemistry course seems to be inferior to the conventional chemistry course on the basis of the results on the ACS test and subtests. This conclusion can be supported on the basis that this investigator made allowances relative to the subtests and the decreased syllabus for the integrated course. (See Appendix D)

Discussion

From the results of the evaluation instruments used, it is evident that there was a significant difference in the mastery of subject matter and development of critical-thinking abilities in favor of the control group (students in conventional chemistry course). This difference was not as great in the critical-thinking abilities developed as it was in chemistry content mastered.

The negative results of this study seem to provide sufficient evidence to warrant dropping the integrated science program in favor of the conventional course. These results were based on the ACS test and not on the CTA test. The CTA test is essentially independent of the ACS test.

It is the conviction of this investigator that the integrated course has promise and should still be used but some changes should be made. Observations and discussions with the students in the integrated course indicated the course was successful regardless of the poor showing on the examination.

This study attempts to compare only one of several types of integrated courses. The following recommendations list some studies that should be made in order that the integrated program can be properly evaluated.

The elimination of the integrated course on the basis of this study would be a mistake; however, should subsequent studies reveal similar results, then the integrated course should not be used as a replacement for the conventional course.

Recommendations

As a result of this study it is recommended that:

1. A study should be made of the student in a physics-chemistry course subsequent to the integrated program. This would indicate whether the integrated course adequately prepares the student for advanced work.
2. A further study should be made using the various parts of the Watson-Glaser test as they relate to the processes of learning in the physical sciences. Some of these areas are inference, recognition of assumptions, deduction and interpretation, and evaluation of arguments.
3. A study should be made concerning different techniques of teaching an integrated course. One such technique might be the approach to subject matter historically.
4. A study should be made about the attitudes of students toward the integrated course. This study could be carried out by the following design:

R_1	O_1	X_1	O_2	O_3
R_2	O_1		O_2	O_3
R_3	O_1		O_2	O_3

R_1 - An integrated physics-chemistry course.

R_2 - A conventional chemistry course.

R_3 - A conventional physics course.

O_1 - A pretest consisting of the Watson-Glaser CTA, Form Ym.

O_2 - A post-test consisting of CTA, Form Zm.

O_3 - A test on understanding science such as TOUS.

Further investigation could be carried out by having each student complete a questionnaire on attitudes toward science.

5. A study should be made in liberal arts colleges using the following experimental design:

R_1	O_1	X_1	O_2	O_3	O_4
R_2	O_1	X_2	O_2	O_3	O_4
R_3	O_1		O_2	O_3	
R_4	O_1		O_2		O_4

R_1 - An integrated physics-chemistry course of three semesters duration. (Similar to the Claremont program.)

R_2 - An integrated physics-chemistry course of four semesters duration. (Similar to the Bryn Mawr program.)

R_3 - A conventional chemistry course.

R_4 - A conventional physics course.

X_1 - The experimental course of three semester duration.

X_2 - The experimental course of four semester duration.

O_1 - A pretest consisting of the Watson-Glaser CTA Test, Form Zm.

O_2 - A post-test consisting of the Watson-Glaser CTA Test, Form Ym.

O_3 - A post-test consisting of the ACS Chemistry Test, Form 1965, and sub-tests.

O_4 - A post-test consisting of a physics test constructed by college physics teachers not associated with this research study.

In this proposed study each of the population groups, R_1-R_5, should have a population number of about 100 students.

The experimental design as described above presents some problems as it is much more complex than most designs. Time is an important factor as the design asks for four tests to be given. These tests are necessary in order to present the data needed to evaluate the program described. Another problem that would be encountered would be assembling the population groups listed. There are colleges that are presently using courses listed as R_1 and R_2. Careful planning would be necessary to coordinate the administration of the tests at the proper times, i.e. at the end of the course. Some of the courses would be of two semester duration and others would be of three and four semesters.

The analysis of data should be handled in a manner similar to the procedure used in Chapter IV of this research study.

In this proposed study, the investigator will be able to get comparisons between the integrated course of varying lengths (three and four semester) and conventional physics and chemistry courses.

This proposed type of study would have a tendency to eliminate some of the biases that existed in this current study.

6. The integrated course should not be abandoned as a result of the outcome of this study. Schools that have the ability to change their curricula and experiment with different types of courses should certainly try the integrated courses described herein.

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APPENDICES

APPENDIX A

COLLEGES PARTICIPATING IN STUDY

College	Central Methodist College (6)
Location (population)	Fayette, Missouri (3294)
Demonimation	Methodist Church
1966-67 Enrollment	935
Year Founded	1853
Accrediting Agency	North Central Association of Colleges and Secondary Schools
Tuition for Academic Year	$825.00
Textbook used in General Chemistry	General College Chemistry, Kennan and Wood. 3rd Ed. Harper
Objectives of School	1. Provides an atmosphere for the student to learn, to think and to develop an appreciation of the view-points of others. 2. Provides a religious atmosphere to develop a dynamic Christian character by study of the Bible and Christian literature. 3. Enriches life of the student through application of the arts and sciences to every day activities.

Entrance Requirements	1.	A high school graduate with a minimum of fifteen acceptable high school units.
	2.	Preference for admission is given to students in the upper third of their high school class. Students in the middle third of their class are eligible for admission.
	3.	Freshman class size limit is about 300.

College	McPherson College (34)
Location (population)	McPherson, Kansas (9996)
Denomination	The Church of Brethren
1966-67 Enrollment	754
Accrediting Agency	North Central Association of Colleges and Secondary Schools
Tuition for Academic Year	$705.00
Textbook used in General Chemistry	College Chemistry, King and Caldwell, American Book Co., 4th Ed.
Objectives of School	McPherson College is a liberal arts college whose aims and purposes are summarized as follows: 1. Liberal education is emphasized. 2. Religious development is fostered. 3. Professional education is offered. 4. Personal development is sought.
Entrance requirements	1. A graduate from an approved secondary school with a satisfactory record. 2. Good character and purpose. 3. Academic and personal achievement such to give promise for

success in college.

4. Prospective students must take the American College Testing program examinations.

College	Tarkio College (42)
Location (population)	Tarkio, Missouri (2160)
Denomination	United Presbyterian Church
1966-67 Enrollment	705
Year Founded	1883
Accrediting Agency	North Central Association of Colleges and Secondary Schools
Tuition for Academic Year	$1,110.00
Textbooks used in Integrated Course	College Physics, Weber, White and Manning, McGraw-Hill, 4th Ed. Chemistry, Sienko and Plane, McGraw-Hill, 2nd Ed.
Objectives of School	Tarkio College is a liberal arts college whose primary aid is: "To assist in the development of young men and women who will be able to meet the needs of their world and accomplish the purpose of their Creator."
Entrance Requirements	1. Prospective students must show evidence of scholastic ability, sincerity of purpose, leadership and other desirable traits. 2. Information to be provided for

evaluation includes: academic record, scholastic tests and recommendations from secondary schools.

College	William Penn College (46)
Location (population)	Oskaloosa, Iowa (11,053)
Denomination	Friends
1966-67 Enrollment	858
Accrediting Agency	North Central Association of Colleges and Secondary Schools
Tuition for Academic Year	$915.00
Textbook used in General Chemistry	Chemistry, Sienko and Plane, McGraw-Hill, 2nd Ed.
Objectives of School	1. Provides a full understanding of the Christian religion with its personal and local implications. 2. Provides integrated general education studies in humanities, natural sciences, social sciences and to develop skills in communication. 3. Provides a course in pre-professional and professional areas. 4. To develop a sense of personal responsibility for society.
Entrance Requirements	1. For admission, the following

are taken into consideration:
general life and character,
academic record, test scores,
achievements and recommenda-
tions.

APPENDIX B

GOURMAN REPORT *

	C[a]	M[b]	T[c]	W[d]
Gourman Rating	354	344	361	350
Academic Rating	382	407	371	357
Chemistry Department	C	C	C	C
Biology Department	C	C	C	C
Physics Department	C	C	C	D
Math Department	C	C	C	C
Library	D	D	D	D

Rating Scale A, B, C, D

A - 800

B - 600

C - 400

D - 200

*Scale compiled by Professor Jack Gourman, San Fernando Valley State College, Northridge, California (23)

a - Central Methodist College Fayette, Missouri

b - McPherson College McPherson, Kansas

c - Tarkio College Tarkio, Missouri

d - William Penn College Oskaloosa, Iowa

APPENDIX C

COURSE SYLLABUS - CONTROL GROUP

I Basic Concepts

A. Metric system

B. Basic laws

II Symbols, Formulas, and Equations

III Structure of the Atom and Periodic Law

A. Fundamental particles

B. Atomic weight

C. Atomic separation

IV Chemical Bond

A. Oxidation numbers and valence

B. Ionic bond

C. Covalent bond

D. Nomenclature

V Oxygen and Hydrogen

VI Acids, Bases and Salts

A. Neutralization

B. Titration

C. Heat of reaction

VII The Gaseous State

A. The kinetic theory of matter

B. The molecular theory of matter

VIII The Liquid and the Solid State

A. Intermolecular forces

B. Vaporization

C. Freezing

D. Crystals and crystal systems

IX Water

A. Structure and properties

B. Hydrates

C. Water as a solvent

X Solutions

A. Concentrations

B. Solubility

C. Colligitive properties

D. Electrolytes and non-electrolytes

XI Oxidation-Reduction

A. Oxidation state

B. Balancing redox equations

C. Gram-equivalent weight

XII Chemical Equilibrium

A. Collision theory

B. Rate of reaction

C. Activation energy

D. Law of mass action

E. Equilibrium constants

XIII Halogens

XIV Electrochemistry

A. Voltaic and electrolytic cells

B. Faraday's Law

C. Anode and cathode

D. Standard electrode potentials

E. Potentiometer

XV Sulfur and Sulfur Compounds

XVI The Active Metals

XVII The Heavy Metals

XVIII Phosphorus, Boron and Other Non-metals

XIX Nuclear Chemistry

A. Natural radioactivity

B. Isotopes

C. Fission and fusion

XX Quantum Theory

In addition to the lecture course, the control group was exposed to laboratory experiences which included:

I Scientific Observations and Chemical Change

II Preparation and Properties of Elements

A. Oxygen

B. Hydrogen

C. Nitrogen

III Catalysis

IV Acids and Bases

V Reactivity and the Activity Series

VI Quantitative Technique

VII Molecular Formula

VIII Qualitative Analysis

A. Semimicro technique

B. Cation analysis

C. Anion analysis

APPENDIX D

COURSE SYLLABUS - EXPERIMENTAL GROUP

I Measurements

A. Mathematics

B. Systems of measurement

C. Coordinate systems

II Systems of Discrete Particles

A. Atoms, sub-atomic particles

1. Electrons, protons and neutrons

2. Atomic structure

3. Quantum mechanical picture

B. Particle Motion

1. Uniform motion

2. Velocity

3. Acceleration

4. Vectors and statics

5. Force, weight

6. Friction

C. Energy

1. Work, power

2. Kinetic and potential energy

3. Momentum

4. Harmonic motion

5. Chemical energy
6. Energy levels in atoms
7. Bohr theory of atomic structure
8. Atomic structure

III Systems of Aggregates of Particles

A. Atoms, molecules and compounds

1. Periodic system
2. Chemical properties of matter
3. The chemical elements

B. Chemical bond and chemical reactions

1. Oxidation number and valence
2. Symbols and formulas
3. Ionic bond
4. Covalent bond
5. Stoichiometry
6. Acids, bases and salts
7. Ionization and dissociation

IV Kinetics and Equilibrium

A. Reaction rate

B. Equilibrium

1. Law of mass action
2. Ionic equilibrium
3. Catalysis

V Heat and Thermodynamics

A. Thermometry and thermal expansion

B. Energy and heat

1. Change of state

2. Calorimetry

3. Transfer of heat

C. Heat of reaction

D. Kinetic theory

E. Gas laws

VI Matter

A. Physical properties of matter

1. Density

2. Specific gravity

B. Gaseous state

C. Liquid state

1. Properties of liquids

2. Hydrostatics

3. Hydrodynamics

4. Water

a. Solutions

b. Water as a solvent

c. pH

D. Solid state

1. Crystals and crystal systems

2. Metals

a. Metallic bond

b. The active metals

c. The heavy metals

3. Non-metals

VII Electricity and Magnetism

A. Fields

1. Electrostatic fields

2. Electromagnetic fields

B. Moving charges

1. Current, voltage and resistance

2. Circuit theory

C. Magnetic materials

D. Electro-chemistry

1. Voltaic cell

2. Faraday's Law

3. Oxidation-Reduction

E. Alternating current

1. Induced emf

2. Inductance

3. Capacitance

VIII Wave Motion

A. Nature of waves

B. Wave propagation

C. Sound waves

D. Light

1. Reflection, refraction

2. Diffraction

3. Lens and optical instruments

4. Interference

5. Polarization

IX Descriptive Organic Chemistry

A. Carbon

B. Hydrocarbons

1. Carbon bonds

2. Hybrid bonds

C. Alcohols, esters and ketones

D. Other derivatives of carbon

E. P, N and S compounds of carbon

In addition to the lectures, the students in the experimental group had laboratory experiences that included:

I Resolution and Composition of Forces

II Accelerated Motion

III Conservation of Mass in Chemical Reactions

IV Centripetal Force

V Molecular Weight of CO_2

VI Gas Laws

VII Formula of a Compound

VIII Hooke's Law and Harmonic Motion

IX Titration

X Calorimetry

XI Ohm's Law and Circuits

XII Halogens

XIII Oxidation-Reduction

XIV Electro-chemistry

XV Equilibrium

XVI Sound

XVII Polarization and Diffraction