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A COMPARATIVE ANALYSIS OF THE EFFECTS OF LABORATORY EXPERIENCE ON THE COGNITIVE DEVELOPMENT OF STUDENTS IN CHEMISTRY

by

STANLEY JEFFERY HILL

A professional paper submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree

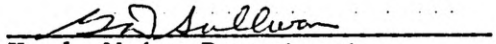
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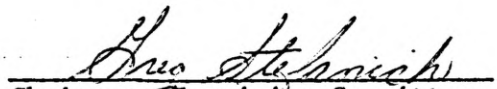
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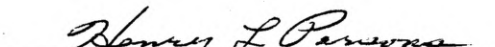
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June, 1974

ACKNOWLEDGMENTS

This writer gladly acknowledges Dr. Albert Suvak and Dr. Gregory P. Stefanich for initiating my interest in this study and for their continual guidance and valuable criticisms on earlier drafts of this manuscript.

I am further indebted to Dr. Suvak for his help in the analysis of my statistics and to Dr. John Amend for his help in the conception and data provisions made for this study.

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ABSTRACT

This investigation measured the differences that exist between those students who took laboratory (Chem 125) with a lecture course (Chem 121) and those students who did not take laboratory (Chem 125) with a lecture course (Chem 121) by measuring the cognitive development in chemistry for each student. The population included all the students matriculating at Montana State University during the fall and winter quarters in 1972 who were enrolled in Chemistry 121. The investigation also measured the differences that exist among nine different curricula in terms of the final grades that were received by the students enrolled in Chemistry 121.

Eight hypotheses were advanced to analyze four different groups of students who were classified as follows:

High School Chemistry and Laboratory (Chemistry Lab 125)
High School Chemistry and No Laboratory
No High School Chemistry and Laboratory (Chemistry Lab 125)
No High School Chemistry and No Laboratory

T-tests were used as the test statistic for hypotheses A, B, C, D, E, and F. Analysis of covariance was used as the test statistic for hypotheses G and H. The level of significance required to reject the null hypotheses was set at the 0.05 level of significance.

Summary of the findings were:

1. The examination of the results showed that significant differences existed between the classified groups that were used in this study.
2. The statistical results indicate that the group of students who had high school chemistry and also took Chemistry Laboratory 125 had significantly higher test scores than any other group. The influence that the high school chemistry experience variable had on test scores was found to be significant only if the chemistry laboratory variable was also present.
3. When the total population of this study was compared using laboratory experience and no laboratory experience as the variables, it was found that the group that took Chemistry Laboratory 125 had significantly higher test scores than the group that did not take Chemistry Laboratory 125.
4. When a comparison was made using student curricula as the variables, it was found that significant differences exist among the nine designated curricula. Among the groups who were identified by a specific curriculum, those students majoring in education received the highest test scores, while those students majoring in home economics received the lowest test scores.

Chapter 1

INTRODUCTION

The continual and rapid growth of scientific technology present today has produced challenges for which most of the participants in today's society are largely unprepared. Since there is no evidence that this trend will not continue, the role that science education is to play will require adequate preparation for the non-scientist as well as for the scientist. In order that this may be accomplished, science educators have been reexamining the goals, objectives, and teaching approaches that are currently in practice.

As a result, new curricula have been developed which purport to offer students a better knowledge and understanding of the fundamental concepts of both the biological and physical sciences. Many of these innovative curricula involve the science students using an experience and material centered approach which transforms the traditional classroom into a laboratory. Students involved in this type of classroom setting are believed to develop a more free and inquisitive attitude, develop skills in rational scientific procedures related to problem solving, develop skills in the examination of observation of objects, organisms, and natural phenomena, as well as developing skills in manipulating and recording data.

While most of the innovative approaches in science education differ mainly in types of materials, subject area emphasis and spiral

or non-spiral curriculum development, all of them emphasize an experience centered approach which asserts itself as being of primary importance in the development of scientific literacy.

Statement of Problem

The purpose of this study is to determine what differences exist between those students who take laboratory (Chem 125) with a lecture course (Chem 121) and those students who do not take laboratory (Chem 125) with a lecture course (Chem 121) by measuring the cognitive development in Chemistry of each student.

The evaluation of student cognitive development in chemistry will be based on individual student performance in lecture examinations. Student performance in laboratory examinations will not be part of and will not influence the final grades received in the lecture course.

Need for the Study

In recent years, the traditional method used in chemistry instruction at the secondary and post-secondary levels has been experiencing broad transitional changes. As a result of critical studies in the improvement of chemistry instruction curricula, these changes have been focused towards a more material and experience centered approach.

These changes have been focused towards a more material and experience centered approach as the result of critical studies in the improvement of curricula in chemistry instruction.

At the present time, there is considerable evidence that the Bozeman Public Schools will initiate experience and material centered pilot curricula as part of their chemistry instruction program. This study will provide additional research and design for the evaluation of these curricula when compared to the traditional programs in chemistry instruction.

Questions To Be Answered

The research techniques that will be implemented in the study will attempt to answer what relationships exist, if any, between students who have had laboratory experiences in chemistry when compared to students who have not had laboratory experience in chemistry, using the results of associated lecture examinations as a measure of the student's cognitive development in the subject of chemistry. In addition, the following specific questions will be examined:

1. Do differences exist between students who had experience in high school chemistry and also had laboratory experience at Montana State University and those students who had high school chemistry but had no laboratory experience at Montana State University?

2. Do differences exist between students who had experience in high school chemistry and also laboratory experience at Montana State University and those students who did not have experience in high school chemistry but had laboratory experience at Montana State University?

3. Do differences exist between students who had high school chemistry and laboratory experience at Montana State University and those students who did not have high school chemistry experience and did not have laboratory experience at Montana State University?

4. Do differences exist between those students who had high school chemistry but did not have laboratory experience at Montana State University and those students who did not have high school chemistry but had laboratory experience at Montana State University?

5. Do differences exist between those students who had high school chemistry but did not have laboratory experience at Montana State University and those students who did have high school chemistry and did not have laboratory experience at Montana State University?

6. Do differences exist between those students who did not have high school chemistry experience but had laboratory experience at Montana State University and those students who did not have experience in high school chemistry and did not have laboratory experience at Montana State University?

7. Do differences exist among the final grades in various student curricula when the student's predicted grade point averages are held constant?

8. Do differences exist between students who have had laboratory experience and those students who have not had laboratory experience when their verbal and math aptitutdes and their predicted grade

point averages are held constant?

General Procedures

This study is based on data that was gathered on a selected group of students who were attending Montana State University located in Bozeman, Montana.

The population included all the students matriculating at Montana State University during the fall and winter quarters of 1972 who were enrolled in Chemistry 121.

The following data was gathered and was used as the basis for this study.

1. The students were categorized into the following general curriculum groups:

a. No designation
b. Agriculture
c. Nursing
d. Home Economics
e. Education
f. Mechanical Engineering
g. Civil Engineering
h. Other Engineering
i. Other Curricula

2. The final grades received in Chemistry 121 by each individual student during the fall and winter quarters of 1972 at Montana State University were recorded.

3. The students enrolled in Chemistry 121 were classified according to the following variables:

a. Not enrolled in laboratory (Chem 125)

b. Enrolled in laboratory (Chem 125)

c. Did not complete a course in high school chemistry

d. Completed a course in high school chemistry

e. Verbal and quantitative aptitudes as computed by the Testing and Counseling Service at Montana State University

f. Predicted grade point averages as computed by the Testing and Counseling Service at Montana State University

In order to analyze the preceding questions, the following statistical instruments will be employed:

1. T-tests will be used for questions one through six (pages 3 through 4).

2. Analysis of covariance will be used for questions seven through eight (pages 4 and 5).

3. The level of significance will be determined at the .05 level.

Limitations

The following limitations are placed on this study.

1. The sample included only those students enrolled in Chemistry 121 and 125 during the fall and winter quarters of 1972 at Montana State University.

2. Student enrollment in laboratory (Chem 125) was optional and did not involve a random selection process.

3. Laboratory (Chem 125) sessions were taught by different assistants.

4. The final grades in Chemistry 121 represent an evaluation of relative success and achievement by only one instructor.

Definitions of Terms

Activity-centered. A classroom or laboratory or outdoor setting which involves students in simulated and actual activities which are relative to the subject matter under investigation.

Predicted grade point average. A composite of commercial and local university evaluative instruments used to develop normative indices as computed by the Testing and Counseling Service at Montana State University.

Chemistry 121. Introduction to General and Biological Chemistry. An elementary course requiring a minimum background of chemistry for biologically-oriented careers. Chemical bonding, radiochemistry, colloids and solutions, acid-base systems, and selected areas of organic and biological chemistry are topics covered in the course.

Chemistry 125. Introduction to General and Biological Chemistry Laboratory. A laboratory to accompany lectures in Chemistry 121 and 122. Experiments with basic laboratory techniques to illustrate principles of chemistry discussed in lecture.

High school chemistry. The successful completion of at least one semester in chemistry from an accredited high school.

Experience centered. A classroom or laboratory or outdoor setting which involves students in simulated and actual activities which are relative to the subject matter under investigation.

Material centered. A classroom or laboratory or outdoor setting which involves students in the use of tools, samples, specimens, and supplies.

Summary

The rapid growth of scientific technology has created an atmosphere of skepticism and indifference towards scientific appreciation and understanding to most of the participants in twentieth century life. Public education has responded to this challenge by presenting a myriad of developmental science curricula which are designed to better prepare the general population for the ever increasing complexities of life in a scientifically oriented century. Many of the latest curriculum developments involve an activity-centered approach in the study of science.

It is the purpose of this study to compare students who have had laboratory experiences and students who have not had laboratory experiences in freshmen chemistry. The cognitive development of the

students in each group was measured using examinations written by Dr. John Amend, Associate Professor of Chemistry, the course instructor.

Chapter 2

REVIEW OF RELATED LITERATURE

Traditionally, chemistry courses have included laboratory work as a necessary and vital part of instruction. This practice has been common to both secondary chemistry, as well as college freshman chemistry. There has been a consistent and continuing effort to improve instruction and student performance in chemistry through the use of innovative laboratory and lecture techniques. As a result, numerous studies have been conducted in an effort to determine what factors influence and raise the general level of cognitive development of students involved in the study of chemistry.

Historically, the early research efforts concentrated predicting the performance of students who study chemistry based on the effects of previous experience in chemistry, academic records from high schools, areas of academic concentration and the results of administered intelligence and academic achievement tests. Later efforts starting in the mid 1950's have concentrated more on the role science was to play in the United States. The research has been directed towards the relationship of society to science, the scientist, values, curricula, and teaching techniques.

The new direction of research in the field has resulted in the emergence of several new high school science programs. In the field of chemistry, the Chemical Bond Approach (CBA) and the Chemical

Education Material Study (CHEM Study) are typical examples of opposing trends to the traditional approach in chemistry instruction.

Robert W. Heath and David W. Stickell, in their study of CHEM and CBA effects on achievement in chemistry, stated the following, "One of the characteristics which helps to distinguish these courses from traditional courses is the emphasis they give to laboratory and research techniques (1963:45)."

Among the more frequent criticisms leveled at traditional methods of classroom chemistry had been that which dealt with a purported memorization of facts on the part of the student. Further, the laboratory work required attempts, generally though unsuccessful, to prove to the student what he already knows, rather than enabling him to discover new ideas (Weinstock, 1972:781).

If today's science educators are to meet the challenges of our society and respond to the expectations and needs of today's students, continued research in the development of new curricula and the relationships of the same to student academic performance must be pursued.

The review of literature has been organized into three sections: a brief review of some recent chemistry curriculum developments, experimentation with innovative laboratory techniques, and the determining factors of student achievement in chemistry.

Recent Curricula Developments

With the launching of the Russian built satellites in the late 1950's and with the ensuing fervor within the scientific community brought about by this development, science educators throughout the United States began a thorough reexamination of the existing science curricula.

To remedy various purported faults in the traditional teaching of high school chemistry, a writing conference of chemists was held in June of 1967. The outcome of it was the Chemical Bond Approach (CBA). The laboratory section of CBA was comprised of three groups: specific direction for the student in order for him to make observations during the experiment, presentation of just enough information to enable the student to actually begin the experiment, and the third group was to deal with the problem itself (Weinstock, 1972:783).

In 1960, the Chemical Education Material Study (CHEM Study) grew out of a conference of chemists having been funded by a grant from the National Science Foundation. This course concentrated on chemical experimentation and observation in an effort to develop chemical concepts. Students were expected to conduct experiments before any material was read or previously discussed with the intention of discovery of fundamental ideas and concepts being of primary importance (Weinstock, 1972:783).

At the present time, there is a variety of opinions among

science educators as to the total effectiveness of both CBA and CHEM Study as for each proponent of these programs there appears equal opponent views (Weinstock, 1972:784-787).

Innovative Laboratory Techniques

The traditional laboratory approach in chemistry uses a deductive process whereby the laboratory is used primarily to confirm facts and principles previously presented in the lecture sessions. The use of laboratory manuals with completion type questions are most typically used to reinforce factual material and previously known principles. George Charen, Jersey City State College, states the following:

> One of the major criticisms leveled at the prevailing deductive method of laboratory teaching has been that it failed to provide genuine problem-solving experiences which cannot be simulated. The emphasis on memorization and verification of the known was often at the expense employed by scientists in the search for nature's truths (1966:267-268).

In Charen's study of attitude building through the use of inductive laboratory techniques, he employed the use of open-ended experiments that were produced by the Manufacturing Chemists' Association (MCA) in 1957. This was based on the premise that attitudes do affect learning and that building positive attitudes is well recognized as being a major objective of science teaching. A questionnaire was developed to measure student feelings, emotional reactions, interest, curiosity and stimulation. Based on the data obtained from this

questionnaire, 72 per cent of the high IQ students favored MCA experiments when compared to traditional experiments, while 63 per cent of the mid IQ and 54 per cent of the low IQ students favored MCA experiments when compared to traditional experiments (1966:268-269).

In a study which attempted to appraise whether problem-solving can be developed in a general chemistry laboratory conducted by Earl J. Montague (1964), the control group performed the usual laboratory manual experiments, while the experimental group was given a series of problem-solving experiences which involved open-ended experiments. The author developed a post-test to measure abilities in an actual laboratory problem situation. Significant differences between the control group and the experimental group were measured using analysis of covariance. The performance test mean for the experimental group was 29.14, while that of the control group was 24.60. Analysis of covariance yielded a t of 6.08 indicating a significant difference between the two groups. As a result of the study, Montague made the following statement:

> It can be concluded that the ability of the experimental group to solve problems in an actual laboratory situation, as measured by the performance test, was significantly greater than that of the control group (1964:37).

In relation to the degree laboratory methods can stimulate critical thinking, a study was conducted using the Manufacturing Chemists' Association (MCA) laboratory approach. The purpose of the study was to compare a selected sample of MCA experiments for the high

school chemistry laboratory with comparable, traditional laboratory exercises. The investigator developed and administered tests in critical thinking and found that there was no significant difference between the MCA and the traditional laboratory approach. The administration of the Watson-Glaser Appraisal yielded a significant difference in favor of the traditional approach (Charen, 1970:267). Charen stated the following conclusion, "In view of the results of the author's study and the present emphasis on the laboratory, another measure of critical thinking, namely a proficiency test, should be devised (1970: 267)."

Achievement in Chemistry

The value of high school chemistry to those students who subsequently enroll in college chemistry courses has been a subject of debate resulting in studies dating back to the 1920's.

Research on this topical matter was carried out by Ira D. Garard and Thalia B. Gates (1929:514) in 1929 using objective written examinations as a measure of student performance. Data was collected on 1,553 examination grades in general chemistry involving 216 students from New Jersey College for Women who had previous experience in chemistry at the high school level. The combined test averages resulted in an achievement of 62.8 per cent. A comparable group of 133 students received 955 grades in the same classes who did not have previous experience in high school chemistry had a combined test average of

53.8 per cent.

In a similar study conducted in 1932, L. E. Steiner (1932:533) used a sample of 604 first semester and 500 second semester college students. Letter grades were assigned numerical equivalents as a basis for obtaining averages. The first semester results showed students having high school chemistry experience scoring an average of 7.6 points above the control group which was comprised of a similar number of students who did not have previous experience in high school chemistry. In the second semester, those students having had high school chemistry scored an average of 2.9 points above the control group. The author stated that the probable cause of the second semester difference being substantially less was due to the number of students who dropped chemistry after failing the first semester.

A related study carried out at East State Teachers College in 1952 by Byron Williams and H. M. Lafferty (1952:214) collected data on their first year chemistry students enrolled during the 1948-49 and 1949-50 school terms. A total of eleven interval tests were administered during each school term and the results were tabulated on a numerical basis. Based on a combined average, students having had high school chemistry scored 9.9 points higher than those students not having had previous high school chemistry experience.

F. D. Martin (1942:274) examined a group of approximately 1,000 engineering students who were enrolled at Purdue University. The

purpose of the study was to examine the student failure rates in various areas of curricula. It was found that the failing grades given the first semester to all engineering students were as follows: 28.2 per cent were given in mathematics, 19.4 per cent in English, 19.0 per cent in chemistry, and 33.4 per cent in other subjects. Martin summarized these results with the following quote, "Those who have trouble with chemistry are generally poor in reading, writing, and arithmetic."

In 1952, John P. McQuary 1952:462) researched what factors determine student achievement in first-year college chemistry at the University of Wisconsin by analyzing the records of students in two general chemistry courses. Two groups of students were identified: those having a background in high school chemistry (G1) and those not having a background in high school chemistry (G2). No differences of any significance in non-intellectual characteristics, such as sex, size of home community, and state residence was noted. Group G2 showed stronger intellectual tendencies in mathematical appitudes, science achievement, and reading comprehension scores. Intellectual variables were highly correlated with grades received in chemistry. The students who have had chemistry in high school are as a group superior in all to the students who have not had high school chemistry.

Summary

The rapid growth of scientific technology has placed an increasing demand on science educators to develop curricula that will adequately prepare our society for participatory roles in a century that is likely to experience greater technological advancements in its concluding quarter than it has witnessed in its previous three quarters. If science educators are to meet this challenge, a complete commitment to continued research in all areas of science education is of paramount importance. The current curricula inadequacies together with the pressing demand for remediation should serve well to provide the necessary impetus to properly direct our professional energies and personal priorities.

Chapter 3

PROCEDURES

The purpose of this study was to determine what differences exist in terms of cognitive development in chemistry between those students who take laboratory (Chem 125) with a lecture course (Chem 121) and those students who do not take laboratory (Chem 125) with a lecture course (Chem 121).

A discussion of the procedures for collecting, organizing, and presenting data for this study will be presented in this chapter.

Population Description and Sampling Procedure

The population of this study included all the students matriculating at Montana State University during the fall and winter quarters in 1972 who were enrolled in Chemistry 121.

The sample of the population confined this study to the extent that it will include only those students who have a complete data description file that meets the data criterions prescribed for this study.

Investigation Description

The data used in this study will be classified in the following manner:

1. Curriculum categories: (a) no designation; (b) agriculture; (c) nursing; (d) home economics; (e) education; (f) mechanical

engineering; (g) civil engineering; (h) other engineering; and (i) other curricula.

2. Student evaluation: The final grades received in Chemistry 121 by each student during the fall and winter quarters at Montana State University were recorded.

3. Classification variables: The students enrolled in Chemistry 121 were classified according to the following variables: (a) not enrolled in laboratory (Chem 125); (b) enrolled in laboratory (Chem 125); (c) did not complete a course in high school chemistry; (d) completed a course in high school chemistry; (e) verbal and quantitative apptitudes as computed by the Testing and Counseling Service at Montana State University; and (f) predicted grade point averages as computed by the Testing and Counseling Service at Montana State University.

Method of Collecting Data

The data used for this study was collected in the following manner:

1. The students enrolled in Chemistry 121 recorded information on tabulating cards pertaining to their curriculum and indicated whether they were enrolled in Chemistry Laboratory 125 and if they had taken chemistry at the high school level.

2. The final grades received by the students who were enrolled in Chemistry 121 were recorded and transcribed on tabulating cards by

the course instructor.

3. This researcher recorded the following information using Montana State University permanent records as a source: (a) university predicted grade point average (UPGPA) as computed by the Testing and Counseling Service at Montana State University; and (b) composite test scores consisting of verbal and quantitative aptitudes that were administered by the Testing and Counseling Service at Montana State University.

4. All recorded data were keypunched and verified on standard tabulating cards and were processed by a computer.

Method of Organizing Data

Data obtained for this study was presented using the following tables of comparison:

1. Tables of T tests
2. Tables of Analysis of Covariance

Statistical Hypotheses

The following statistical hypotheses were advanced for this study:

Hypothesis A. H_o - There is no significant difference between students who had experience in high school chemistry and also had laboratory experience at Montana State University and those students who had high schcol chemistry but had no laboratory experience at

Montana State University.

H_1 - There is a significant difference between students who had experience in high school chemistry and also had laboratory experience at Montana State University and those students who had high school chemistry but had no laboratory experience at Montana State University.

Hypothesis B. H_o - There is no significant difference between those students who had experience in high school chemistry and also laboratory experience at Montana State University and those students who did not have experience in high school chemistry but had laboratory experience at Montana State University.

H_1 - There is a significant difference between those students who had experience in high school chemistry and also laboratory experience at Montana State University and those students who did not have experience in high school chemistry but had laboratory experience at Montana State University.

Hypothesis C. H_o - There is no significant difference between those students who had high school chemistry and laboratory experience at Montana State University and those students who did not have high school chemistry experience and did not have laboratory experience at Montana State University.

H_1 - There is a significant difference between those students who had high school chemistry and laboratory experience at Montana State

University and those students who did not have high school chemistry experience and did not have laboratory experience at Montana State University.

Hypothesis D. H_o - There is no significant difference between those students who had high school chemistry but did not have laboratory experience at Montana State University and those students who did not have high school chemistry but had laboratory experience at Montana State University.

H_1 - There is a significant difference between those students who had high school chemistry but did not have laboratory experience at Montana State University and those students who did not have high school chemistry but had laboratory experience at Montana State University.

Hypothesis E. H_o - There is no significant difference between those students who had high school chemistry but did not have laboratory experience at Montana State University and those students who did have high school chemistry and did not have laboratory experience at Montana State University.

H_1 - There is a significant difference between those students who had high school chemistry but did not have laboratory experience at Montana State University and those students who did have high school chemistry and did not have laboratory experience at Montana State University.

Hypothesis F. H_o - There is no significant difference between those students who did not have high school chemistry experience but had laboratory experience at Montana State University and those students who did not have experience in high school chemistry and did not have laboratory experience at Montana State University.

H_1 - There is a significant difference between those students who did not have high school chemistry experience but had laboratory experience at Montana State University and those students who did not have experience in high school chemistry and did not have laboratory experience at Montana State University.

Hypothesis G. H_o - There is no significant difference among final grades in various student curricula when the student's predicted grade point averages are held constant.

H_1 - There is a significant difference among final grades in various student curricula when the student's predicted grade point averages are held constant.

Hypothesis H. H_o - There is no significant difference between students who have had laboratory experience and those students who have not had laboratory experience when their verbal and math aptitudes and their predicted grade point averages are held constant.

H_1 - There is a significant difference between students who have had laboratory experience and those students who have not had

laboratory experience when their verbal and math aptitudes and their predicted grade point averages are held constant.

Analysis of Data

The statistical treatments of the data included T tests and analysis of covariance. T-tests were used to examine questions 1-6 (pages 3 and 4). Analysis of covariance were used to examine questions 7-8 (Pages 4 and 5).

The level of significance necessary for the rejection of the null hypotheses were set at the 0.05 level.

Precautions Taken for Accuracy

The recording of the final grades that were received by the students were checked by the students who were enrolled in Chemistry 121. The transcription of recorded data from permanent record files were double checked for accuracy by this researcher. All of the data that was keypunched on tabulating cards were verified for accuracy.

Summary

The population used for this study included all the students who matriculated at Montana State University during the fall and winter quarters of 1972 and who also enrolled in Chemistry 121.

A combination of personal, academic performance, and permanent record test data was collected and statistically treated in accordance

with the hypotheses advanced for this study.

Statistical methods used to analyze the data collected for this study are T-tests and analysis of covariance. The level of significance used in testing the hypotheses were set at the 0.05 level.

Chapter 4

ANALYSIS OF THE FINDINGS OF THE STUDY

This chapter will present the analysis of the data and a discussion of the results. An analysis will be done on four groups of students, all of whom had taken a lecture course in chemistry (Chemistry 121) from the same instructor. The groups were classified as follow:

Classification

High school chemistry and laboratory (Chemistry Lab 125)

High school chemistry and no laboratory

No high school chemistry and laboratory (Chemistry Lab 125)

No high school chemistry and no laboratory

Two types of statistical analysis will be made: T-tests will be used for hypotheses A, B, C, D, E, and F. Analysis of covariance will be used to test hypotheses G and H.

Summary of Hypothesis A

Hypothesis A stated that there is no significant difference between students who had experience in high school chemistry and also had laboratory experience at Montana State University and those students who had high school chemistry but had no laboratory experience at Montana State University. A summary of the findings is presented in Table 1, page 28. The null statement was rejected as the computed T

value 2.501 was greater than the table T value 1.96 required to be significant at the .05 level of significance. The alternative

Table 1

Means, Standard Deviation, and T Test Score for Groups with High School Chemistry and Laboratory and High School Chemistry and No Laboratory

Classification	Number of Students	Mean	Standard Deviation	T-Test Score
High School Chemistry and Laboratory	205	108.52	17.86	2.501
High School Chemistry and No Laboratory	65	102.09	18.71	

hypothesis that there is a significant difference between students who had experience in high school chemistry and also had laboratory experience at Montana State University and those students who had high school chemistry but had no laboratory experience at Montana State University was accepted.

Summary of Hypothesis B

Hypothesis B stated that there is no significant difference between students who had experience in high school chemistry and also laboratory experience at Montana State University and those students who did not have experience in high school chemistry but had laboratory experience at Montana State University. A summary of the findings is

presented in Table 2. The null statement was rejected as the computed T value 4.734 was greater than the table T value 1.96 required to be

Table 2

Means, Standard Deviation and T-Test Score for Groups with High School Chemistry and Laboratory and No High School Chemistry and Laboratory

Classification	Number of Students	Mean	Standard Deviation	T-Test Score
High School Chemistry and Laboratory	205	108.52	17.86	4.734
No High School Chemistry and Laboratory	202	99.23	21.57	

significant at the .05 level of significance. The alternative hypothesis that there is a significant difference between those students who had experience in high school chemistry and also laboratory experience at Montana State University and those students who did not have experience in high school chemistry but had laboratory experience at Montana State University was accepted.

Summary of Hypothesis C

Hypothesis C stated that there is no significant difference between students who had high school chemistry and laboratory experience at Montana State University and those students who did not have high school chemistry experience and did not have laboratory experience at Montana State University. A summary of the findings is presented in

Table 3. The null statement was rejected as the computed T value 4.479 was greater than the table T value 1.96 required to be significant

Table 3

Means, Standard Deviation and T-Test Score for Groups with High School Chemistry and Laboratory and No High School Chemistry and No Laboratory

Classification	Number of Students	Mean	Standard Deviation	T-Test Score
High School Chemistry and Laboratory	205	108.52	17.86	4.479
No High School Chemistry and No Laboratory	63	96.57	20.56	

at the .05 level of significance. The alternative hypothesis that there is a significant difference between those students who had high school chemistry and laboratory experience at Montana State University and those students who did not have high school chemistry experience and did not have laboratory experience at Montana State University was accepted.

Summary of Hypothesis D

Hypothesis D stated that there is no significant difference between those students who had high school chemistry but did not have laboratory experience at Montana State University and those students who did not have high school chemistry but had laboratory experience at Montana State University. A summary of the findings is presented

in Table 4. The null statement was not rejected as the computed T value .956 was less than the Table T value 1.96 required to be significant at the .05 level of significance.

Table 4

Means, Standard Deviation and T-Test Score for Groups with High School Chemistry and No Laboratory and No High School Chemistry and Laboratory

Classification	Number of Students	Mean	Standard Deviation	T-Test Score
High School Chemistry and No Laboratory	65	102.09	18.71	.956
No High School Chemistry and Laboratory	202	99.23	21.57	

Summary of Hypothesis E

Hypothesis E stated that there is no significant difference between those students who had high school chemistry but did not have laboratory experience at Montana State University and those students who did have high school chemistry and did not have laboratory experience at Montana State University. A summary of the findings is presented in Table 5, page 32. The null statement was not rejected as the computed T value 1.589 was less than the Table T value 1.96 required to be significant at the .05 level of significance.

Table 5

Means, Standard Deviation and T-Test Score for Groups with High School Chemistry and No Laboratory and No High School Chemistry and No Laboratory

Classification	Number of Students	Mean	Standard Deviation	T-Test Score
High School Chemistry and No Laboratory	65	102.09	18.71	1.589
No High School Chemistry and No Laboratory	63	96.57	20.56	

Summary of Hypothesis F

Hypothesis F stated that there is no significant difference between those students who did not have high school chemistry experience but had laboratory experience at Montana State University and those students who did not have experience in high school chemistry and did not have laboratory experience at Montana State University. A summary of the findings is presented in Table 6. The null statement was not

Table 6

Means, Standard Deviation and T-Test Score for Groups with No High School Chemistry and Laboratory and No High School Chemistry and No Laboratory

Classification	Number of Students	Mean	Standard Deviation	T-Test Score
No High School Chemistry and Laboratory	202	99.23	21.57	.865
No High School Chemistry and No Laboratory	63	96.57	20.56	

rejected as the computed T value .865 was less than the Table T value 1.96 required to be significant at the .05 level of significance.

Summary of Hypothesis G

Hypothesis G stated that there is no significant difference among final grades in various student curricula when the student's predicted grade point averages were held constant. A summary of the findings is presented in Table 7, page 34. The null statement was rejected as the computed F value 3.17 was greater than the Table F value 1.94 required to be significant at the .05 level of significance. The alternative hypothesis that there is a significant difference among final grades in various student curricula when the student's predicted grade point averages are held constant was accepted.

Table 7 presented the mean of the predicted grade point average and the mean, adjusted grade mean, and standard deviation for the final examination grade for each curriculum. Identification of curriculum groups is discussed in Chapter 1, page 5.

Summary of Hypothesis H

Hypothesis H stated that there is no significant difference between students who have had laboratory experience and those students who have not had laboratory experience when their verbal and math aptitudes and their predicted grade point averages are held constant. A summary of the findings is presented in Table 8, page 35, and Table

Table 7.

Mean of Predicted Grade Point Average, Mean, Adjusted Grade Mean and the Adjusted Grade Standard Deviation for Each Curriculum Designation

Group	Number of Students	Predicted G.P.A.	Grade Mean	Adjusted Grade Mean	Adjusted Grade Standard Deviation
No Designation	5	2.10	94.80	98.41	7.83
Agriculture	72	2.24	101.33	102.41	2.06
Nursing	128	2.26	99.87	100.65	1.55
Home Economics	42	2.31	96.00	95.90	2.70
Education	12	2.38	116.50	115.09	5.05
Mechanical Engineering	9	2.14	101.33	104.16	5.84
Civil Engineering	10	2.71	108.60	101.40	5.57
Other Engineering	29	2.36	111.41	110.50	3.25
Other Curricula	89	2.37	108.13	106.99	1.86

F = 3.17 D.F. = 8 and 386

9, page 36. Since the data obtained on the student's math aptitudes was insufficient in number, it was not treated in this study.

Table 8 presents the means of the verbal stanines, the means of the final examination grades, and the adjusted means of the final

Table 8

Means of Verbal Stanines, Means of Final Examination Grades, and the Adjusted Means of the Final Examination Grades for Groups with Laboratory 125 and with No Laboratory 125

Group	Number of Students	Mean of Verbal Stanine	Mean of Final Grade	Adjusted Mean Final Grade
With Laboratory	374	4.94	104.21	103.84
Without Laboratory	115	4.52	98.66	99.85

$F = 4.01$ D.F. = 1 and 486

examination grades. Since the computed F value of 4.01 was greater than the Table F value of 3.84, the hypothesis that there was no significant difference between students who had laboratory and those who did not have laboratory when the verbal stanine was the covariate was rejected. The alternative hypothesis that there is a significant difference between students who have have laboratory experience and those students who have not had laboratory experience when their verbal and math aptitudes and their predicted grade point averages are held constant was accepted.

Table 9 presents the means of the predicted grade point averages, the means of the final examination grades and the adjusted means of the final examination grades. Since the computed F value of 4.62 was

Table 9

Means of Predicted Grade Point Averages, Means of Final Examination Grades, and Adjusted Means of Final Examination Grades for Groups with Laboratory 125 and With No Laboratory 125

Group	Number of Students	Mean of Verbal Stanine	Mean of Final Grade	Adjusted Mean Final Grade
With Laboratory	301	2.29	104.08	104.20
Without Laboratory	95	2.32	100.07	99.70

F = 3.84 D.F. = 1 and 393

greater than the Table F value of 3.84, the hypothesis that there is no significant difference between students who had laboratory and those who did not have laboratory when the predicted grade point average was the covariate was rejected. The alternative hypothesis that there is a significant difference between students who have had laboratory experience and those students who have not had laboratory experience when their verbal and math aptitudes and their predicted grade point averages are held constant was accepted.

Discussion of the Results

The examination of the results showed that significant differences existed between the classified groups that were used in this study. Five of the eight null hypotheses were rejected.

It was found that the group of students who had high school chemistry and also took Chemistry Laboratory 125 had significantly higher test scores than the group of students who had taken high school chemistry but did not take Chemistry Laboratory 125, the group that did not have high school chemistry but took Chemistry Laboratory 125, and the group that did not take high school chemistry and did not take Chemistry Laboratory 125. The influence that the high school chemistry experience variable had on test scores was found to be significant only if the Chemistry Laboratory 125 variable was also present.

When the total population of this study was compared using laboratory experience and no laboratory experience as the variables with verbal aptitudes and predicted grade point averages as the covariates, it was found that the group that took Chemistry Laboratory 125 had significantly higher test scores than the group that did not take Chemistry Laboratory 125.

When a comparison was made using student curricula as the variables, it was found that significant differences exist among the nine designated curricula. Among the groups who were identified by a specific curriculum, those students majoring in education received the

highest test scores, while those students majoring in home economics received the lowest test scores. The reasons for the differences that exist among the curricula are not known at this time, but it may be the result of the small sample size.

Summary

The analysis of the findings was based on the test results of the eight hypotheses that were advanced for this study. For hypotheses A, B, C, D, and E, the total population was classified into four groups:

High school chemistry and laboratory (Chemistry Lab 125)

High school chemistry and no laboratory

No high school chemistry and laboratory (Chemistry Lab 125)

No high school chemistry and no laboratory

It was found that the group of students who had high school chemistry and also took Chemistry Laboratory 125 had significantly higher test scores than any other group. The influence that high school chemistry experience variable had on test scores was found to be significant, only if the Chemistry Laboratory 125 variable was also present.

For hypothesis F the total population of this study was compared using student curricula as variables. It was found that significant differences exist among the nine designated curricula. Among the groups who were identified by a specific curriculum, those students majoring in education received the highest test scores,

while those students majoring in home economics received the lowest test scores.

For hypothesis G and H, the total population of this study was compared using laboratory experience and no laboratory experience as the variables, with verbal aptitudes and predicted grade point averages as the covariates. It was found that the group that had taken Chemistry Laboratory 125 had significantly higher test scores than the group that did not take Chemistry Laboratory 125.

Chapter 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A summary of Chapters 1, 2, 3, and 4, conclusions, and recommendations are presented in this chapter.

Summary

The rapid growth of scientific technology has created an atmosphere of skepticism and indifferences toward scientific appreciation and understanding to most of the participants in twentieth century life. Public education has responded to this challenge by presenting a myriad of developmental science curricula which are designed to better prepare the general population for the ever increasing complexities of life in a scientifically oriented century. Many of the latest curriculum developments involve an activity-centered approach in the study of science.

The purpose of this study was to compare students who have had laboratory experience and students who have not had laboratory experience in freshmen chemistry. The cognitive development of the students in each group was measured using examinations written by Dr. John Amend, Associate Professor of Chemistry, the course instructor.

The population used for this study included all the students who matriculated at Montana State University during the fall and winter quarters in 1972 and who were also enrolled in Chemistry 121. A combination of personal, academic performance and permanent record

test data was collected and statistically treated in accordance with the hypotheses advanced for this study.

Statistical methods used to analyze the data collected for this study were T-tests and analysis of covariance. The level of significance used in testing the hypotheses was set at the 0.05 level.

The analysis of the findings was based on the test results of the eight hypotheses that were advanced for this study. For hypotheses A, B, C, D, and E, the total population was classified into four groups:

High school chemistry and laboratory (Chemistry Lab 125)

High school chemistry and no laboratory

No high school chemistry and laboratory (Chemistry Lab 125)

No high school chemistry and no laboratory

It was found that the group of students who had high school chemistry and also took Chemistry Laboratory 125 had significantly higher test scores than any other group. The influence that the high school chemistry experience variable had on test scores was found to be significant only if the Chemistry Laboratory 125 variable was also present.

For hypothesis F the total population of this study was compared using student curricula as variables. It was found that significant differences exist among the nine designated curricula. Among the groups who were identified by a specific curriculum, those

students majoring in education received the highest test scores, while those students majoring in home economics received the lowest test scores.

For hypotheses G and H, the total population of this study was compared using laboratory experience and no laboratory experience as the variables and verbal aptitude and predicted grade point average as the covariates. It was found that the group that had taken Chemistry Laboratory 125 had significantly higher test scores than the group that did not take Chemistry Laboratory 125.

Conclusions

The examination of the results showed that significant differences existed between the classified groups that were used in this study.

The statistical results indicate that the group of students who had high school chemistry and also took Chemistry Laboratory 125 had significantly higher test scores than any other group. The influence that the high school chemistry experience variable had on test scores was found to be significant only if the chemistry laboratory variable was also present.

When the total population of this study was compared using laboratory experience and no laboratory experience as the variables, with verbal aptitudes and predicted grade point averages as the covariates, it was found that the group that took Chemistry Laboratory

125 had significantly higher test scores than the group that did not take Chemistry Laboratory 125.

When a comparison was made using student curriculas as the variables, it was found that significant differences exist among the nine designated curricula. Among the groups who were identified by a specific curriculum, those students majoring in education received the highest test scores, while those students majoring in home economics received the lowest test scores. The reasons for the differences that exist among the curricula are not known at this time, but it may be the result of the small sample size.

Recommendations

The following recommendations from this study are presented.

1. The conclusions reached by the study are limited to the population of those students who matriculated at Montana State University during the fall and winter quarters in 1972 who were enrolled in Chemistry 121. This study should be replicated using a different population group.

2. A similar study should be done using other populations, such as high school students and possibly elementary school students.

3. A similar study should be done using other subject areas which have a laboratory component.

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