AN ABSTRACT OF THE THESIS OF

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Title: ATTITUDES TOWARD SCIENCE AND CRITICAL THINKING ABILITIES OF CHEMISTRY AND NON-CHEMISTRY STUDENTS IN THE TACOMA PUBLIC SCHOOLS.

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Dr. Fred W. Fox

This investigation was designed to compare the growth in attitudes toward science and the critical thinking abilities of high school juniors in chemistry to juniors not enrolled in chemistry. One hundred and fifty-three chemistry students and 149 non-chemistry students were randomly selected to participate in the study.

Criterion tests used were the Cornell Critical Thinking Test, Form X and the Reaction Inventory, Attitudes Toward Science and Scientific Careers. The study was of a pre-test - post-test design and the criterion tests were administered to the juniors in September and March of the 1966-67 academic year.

To statistically control the academic achievement and academic ability of the students, the following covariance controls were used:

1. The Numerical Ability score on the Differential Aptitude Test.

2. The combined Verbal Reasoning and Numerical Ability score on the Differential Aptitude Test.

3. The Background in Natural Science score on the Iowa Test of Educational Development.

4. The total score on the School and College Ability Test.

5. The accumulative grade point average.

T-tests of significance were used to determine whether differences in group means on the criterion instruments were significant.

The following conclusions were drawn from the investigation:

1. There was no significant difference in the growth in critical thinking abilities between any of the groups of chemistry and non-chemistry students.

2. Chemistry students made greater gains in growth in critical thinking ability than non-chemistry students.

3. When statistically controlling the Numerical Ability score on the DAT, the high subgroup of chemistry students scored significantly higher (.05 level) than did the non-chemistry students in attitudes toward science.

4. Chemistry students made positive gains in growth in attitudes toward science as measured by the Reaction Inventory while the non-chemistry students indicated no positive gains.

Attitudes Toward Science and Critical Thinking Abilities of Chemistry and Non-Chemistry Students in the Tacoma Public Schools

by

Terrance Ralph Brown

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CHAPTER I

INTRODUCTION

Many new science courses have been introduced into the secondary school curriculum. These courses have been developed through the efforts of many conscientious persons and agencies who were interested in the improvement of science teaching and learning.

One of the new courses is the Chemical Education Material Study program (CHEM Study). Woven into its objectives are the acquisition of positive scientific attitudes and a growth in critical thinking abilities. Much of the course is designed to attain these objectives as well as other objectives.

There are many assertions with respect to the need for teaching critical thinking and developing positive attitudes toward science. Taba (96, p. 215-216) listed critical thinking as a type of behavioral objective to be found in an adequate curriculum. She further indicated values and attitudes as being equally important. Tyler (99, p. 35) in an article concerning objectives listed the "development of effective ways of clear thinking" as a basic objective in teaching and noted that these objectives also include the "inculcation of social rather than selfish attitudes". Cronbach (31, p. 299) stated:

> The goals of a curriculum are to teach something beyond specific facts, generalizations, and techniques. We should be more interested in describing how the instruction modifies the student's thinking and attitudes than in assigning a total score to his performance.

The Educational Policies Commission of the National Education Association stressed the importance of critical thinking in its statement (38, p. 4):

> To be free, a man must be capable of basing his choices on understandings which he himself achieves and on values which he examines for himself. He must be aware of the bases on which he accepts propositions as true. He must understand the values by which he lives, the assumptions on which they rest, and the consequences to which they lead. He must be capable of analyzing the situation in which he finds himself and of developing solutions to the problems before him. . . . he has a rational grasp of himself, his surroundings, and the relation between them.

While the aforementioned have indicated some of the objectives it also becomes essential to critically examine the curricula of the schools. New courses-of-study have been introduced by agencies under the sponsorship of the National Science Foundation and other organizations. The work of the various agencies such as the Biological Science Curriculum Study, the Physical Science Study Committee, the Chemical Bond Approach, the Earth Science Project and the Chemical Education Material Study program needs to be continuously and thoroughly evaluated. It is not sufficient to merely construct new courses. Each of these courses needs to be assessed to determine the extent to which their objectives are being attained.

Statement of the Problem

There is a need for an investigation of critical thinking abilities and scientific attitudes of students in science courses. This study was designed to compare the growth in attitudes and the critical thinking abilities of high school juniors in chemistry to juniors not enrolled in chemistry.

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

1. To what extent are CHEM Study and non CHEM Study students proficient in critical thinking abilities as measured by the *Cornell Critical Thinking Test, Form X*?
2. To what extent do CHEM Study and non CHEM Study students possess scientific attitudes as measured by the *Reaction Inventory, Attitudes Toward Science and Scientific Careers*?
3. To what extent do students in the CHEM Study course differ in growth in critical thinking abilities from students not enrolled in CHEM Study?
4. To what extent do students in the CHEM Study course differ in growth in attitudes toward science from students not enrolled in CHEM Study?

The study was purposefully designed to analyze the above questions and was based on the assumption that development of scientific attitudes and critical thinking abilities are essential objectives in the teaching of science.

Hypothesis to Be Tested

The study was designed to test the general hypothesis that eleventh grade students taking Chemical Education Materials Study chemistry have attained a higher degree of growth in critical thinking abilities and a more positive change in attitudes towards science and scientific careers than those eleventh grade students not enrolled in chemistry. It was predicted that the chemistry students would have attained a higher degree of growth in critical thinking abilities and a more positive change in attitudes toward science and scientific careers than those students not enrolled in chemistry.

To test the hypothesis, the following null hypotheses were established to be treated statistically:

1. There is no difference in growth in critical thinking abilities between chemistry students and the critical thinking abilities of non-chemistry students.
2. There is no difference in growth in critical thinking abilities between chemistry students in the high subgroup based upon the total score on the *School and College*

Ability Test and the non-chemistry students in the high subgroup based upon the total score on the *School and College Ability Test*.

3. There is no difference in growth in critical thinking abilities between chemistry students in the low subgroup based upon the total score on the *School and College Ability Test* and the non-chemistry students in the low subgroup based upon the total score on the *School and College Ability Test*.

4. There is no difference in growth in critical thinking abilities between chemistry students in the high subgroup based on the accumulative grade point average and the non-chemistry students in the high subgroup based upon the accumulative grade point average.

5. There is no difference in growth in critical thinking abilities between chemistry students in the low subgroup based upon accumulative grade point average and the non-chemistry students in the low subgroup based upon the accumulative grade point average.

6. There is no difference in growth in critical thinking abilities between chemistry students in the high subgroup based upon the Numerical Ability score on the *Differential Aptitude Test* and the non-chemistry students in the high

subgroup based upon the Numerical Ability score on the _Differential Aptitude Test_.

7. There is no difference in growth in critical thinking abilities between chemistry students in the low subgroup based upon the Numerical Ability score on the _Differential Aptitude Test_ and the non-chemistry students in the low subgroup based upon the Numerical Ability score on the _Differential Aptitude Test_.

8. There is no difference in growth in critical thinking abilities between chemistry students in the high subgroup based upon the combined Numerical Ability and Verbal Reasoning scores on the _Differential Aptitude Test_ and the non-chemistry students in the high subgroup based upon the combined Numerical Ability and Verbal Reasoning scores on the _Differential Aptitude Test_.

9. There is no difference in growth in critical thinking abilities between chemistry students in the low subgroup based upon the combined Numerical Ability and Verbal Reasoning scores on the _Differential Aptitude Test_ and the non-chemistry students in the low subgroup based upon the combined Numerical Ability and Verbal Reasoning scores on the _Differential Aptitude Test_.

10. There is no difference in growth in critical thinking

abilities between chemistry students in the high subgroup based upon the Background in Natural Science score on the _Iowa Test of Educational Development_ and the non-chemistry students in the high subgroup based upon the Background in Natural Science score on the _Iowa Test of Educational Development_.

11. There is no difference in growth in critical thinking abilities between chemistry students in the low subgroup based upon the Background in Natural Science score on the _Iowa Test of Educational Development_ and the non-chemistry students in the low subgroup based upon the Background in Natural Science score on the _Iowa Test of Educational Development_.

12. There is no difference in growth of attitudes toward science between chemistry students and the attitudes toward science of non-chemistry students.

13. There is no difference in growth of attitudes toward science between chemistry students in the high subgroup based upon the total score of the _School and College Ability Test_ and the non-chemistry students in the high subgroup based upon the total score on the _School and College Ability Test_.

14. There is no difference in growth of attitudes toward

science between chemistry students in the low subgroup based upon the total score of the _School and College Ability Test_ and the non-chemistry students in the low subgroup based upon the total score on the _School and College Ability Test._

15. There is no difference in growth in attitudes toward science between chemistry students in the high subgroup based upon the accumulative grade point average and the non-chemistry students in the high subgroup based upon the accumulative grade point average.

16. There is no difference in growth in attitudes toward science between chemistry students in the low subgroup based upon the accumulative grade point average and the non-chemistry students in the low subgroup based upon the accumulative grade point average.

17. There is no difference in growth in attitudes toward science between chemistry students in the high subgroup based upon the Numerical Ability score on the _Differential Aptitude Test_ and the non-chemistry students in the high subgroup based upon the Numerical Ability score on the _Differential Aptitude Test._

18. There is no difference in growth in attitudes toward science between chemistry students in the low subgroup

based upon the Numerical Ability score on the Differential Aptitude Test and the non-chemistry students in the low subgroup based upon the Numerical Ability score on the Differential Aptitude Test.

19. There is no difference in growth in attitudes toward science between chemistry students in the high subgroup based upon the combined Numerical Ability and Verbal Reasoning scores on the Differential Aptitude Test and the non-chemistry students in the high subgroup based upon the combined Numerical Ability and Verbal Reasoning scores on the Differential Aptitude Test.

20. There is no difference in growth in attitudes toward science between chemistry students in the low subgroup based upon the combined Numerical Ability and Verbal Reasoning scores on the Differential Aptitude Test and the non-chemistry students in the low subgroup based upon the combined Numerical Ability and Verbal Reasoning scores on the Differential Aptitude Test.

21. There is no difference in growth in attitudes toward science between chemistry students in the high subgroup based upon the Background in Natural Science score on the Iowa Test of Educational Development and the non-chemistry students in the high subgroup based upon the

Background in Natural Science score on the _Iowa Test of Educational Development._

22. There is no difference in growth in attitudes toward science between chemistry students in the low subgroup based upon the Background in Natural Science score on the _Iowa Test of Educational Development_ and the non-chemistry students in the low subgroup based upon the Background in Natural Science score on the _Iowa Test of Educational Development._

Definition of Terms

Chemical Education Material Study Course (CHEM Study)

The CHEM Study course is the course-of-study prepared through the direction of Dr. Glenn Seaborg, Dr. J. Arthur Campbell, and Dr. George Pimentel under the auspices and support of the National Science Foundation. The course is based upon the concept of using discovery methods in chemistry as a way of presenting the material and information to be learned. Many educational materials are used as part of the course: the text, _Chemistry, An Experimental Science_, an accompanying laboratory manual, an elaborate and detailed teacher's guide, films specifically designed for the course, supplementary student reference books, wall charts, and programmed instruction booklets for the slide rule and power of ten notation.

Critical Thinking

Good (53, p. 424) defined critical thinking as thinking that proceeds on the basis of careful evaluation of premises and evidence and comes to conclusions through the consideration of all pertinent factors. Specifically, the areas of critical thinking included in this study are as follows:

1. Induction: ability to judge whether a simple generalization or hypothesis is warranted.
2. Reliability: ability to judge whether an observation statement is reliable.
3. Deduction: ability to judge whether a statement follows from the premises.
4. Assumption-Finding: Ability to judge whether something is an assumption.

Academic Achievement

Academic achievement is defined as the extent to which the student has mastered the various courses in school and is measured by his accumulative grade point average based on a four point system, selected scores from the *Iowa Test of Educational Development*, and selected scores from the Differential Aptitude Test.

Academic Ability

Academic ability is defined as the capacity the student has for mastering the various courses in school and is measured by his total score on the School and College Ability Test.

Course-of-Study

The term course-of-study is defined by Good (53, p. 109) as an official guide prepared for use by administrators, supervisors, and teachers of a particular school or school system as an aid to teaching in a given subject or area of study for a given grade; it may include the aims of the course, the expected outcomes, and the scope and nature of the materials to be studied, with suggestions as to suitable instructional aids, textbooks, supplementary reading, activities, teaching methods, and measures of achievement.

Learning Outcomes

Learning outcomes are defined as changed behaviors which result from learning (53, p. 38). The term as used in this investigation refers to:

1. The development of desirable attitudes concerning the nature of science and scientific careers.

2. The growth in critical thinking abilities.

Chemistry Student

For this study, the chemistry student is defined as an eleventh grade student enrolled in the following courses-of-study as of September 30, 1966:

CHEM Study chemistry

Foreign language (German, French, Spanish, or Latin)

United States History

Eleventh grade English

Eleventh grade mathematics

Non-Chemistry Student

The non-chemistry student is defined as an eleventh grade student enrolled in the following courses-of-study as of September 30, 1966:

A non-science elective

Foreign language (German, French, Spanish, or Latin)

United States History

Eleventh grade English

Eleventh grade mathematics

Attitude

Attitude is defined by Good (53, p. 48) as a readiness to react toward or against some situation, person, or thing, in a particular manner. More specifically, it is a set of emotionally toned ideas about science, the relation between science and society, the scientist, scientific work, and the scientific enterprise.

Basic Assumptions

In this study it was assumed that:

1. The Cornell Critical Thinking Test, Form X is a valid and reliable instrument for measuring aspects of critical thinking.
2. The Reaction Inventory, Attitudes Toward Science and Scientific Careers is a valid and reliable instrument for measuring attitudes toward science and scientific careers.
3. Critical thinking abilities and attitudes toward science and scientific careers are a major concern of the Chemical Education Materials Study course-of-study.
4. A six month time interval between a pre-test and a post-test is a sufficient time period to forget any knowledge gained from the initial test conditions.
5. Critical thinking abilities and attitudes toward science

and scientific careers can be taught.

6. Critical thinking abilities and attitudes toward science can be analyzed into a number of components for the purpose of evaluation.

7. The teachers involved in the study are teaching the Chemical Education Material Study course as prescribed in the teacher's manual.

8. The student's accumulative grade point average, selected scores on the Differential Aptitude Test and selected scores on the Iowa Test of Educational Development provides a valid and reliable measure of his general academic ability.

9. The student's total score on the School and College Ability Test provides an evaluation of his general academic ability.

10. There are no other variables that will influence the outcomes of the study.

Limitations of the Study

The investigation reported in this study was subject to the following limitations:

1. The problem was limited to the Tacoma High Schools for the school year 1966-1967 to provide a general analysis

of students in chemistry and non-chemistry programs.

2. The study was further limited to selected juniors in the Tacoma High Schools for the school year 1966-1967.

3. The sample for the study was randomly selected from juniors taking eleventh grade mathematics who also were taking the other classes: foreign language, eleventh grade English, United States history.

4. The study was limited to a relatively small group in a single school system thus limiting the extent to which the results can be generalized.

5. Consideration will be made only on the basis of change in attitudes toward science and growth in critical thinking abilities.

6. The school records served as adequate sources of information to determine the academic ability and academic achievement of the students in the sample population.

7. The instrument used to measure the critical thinking abilities was the <u>Cornell Critical Thinking Test, Form X</u>. It was a 50 minute examination limited to the following aspects of critical thinking:

   a. Induction: evaluation of evidence for or against a hypothesis.

   b. Reliability: evaluation of the reliability of information.

c. Deduction: logical reasoning ability.

d. Assumption-finding: recognition of assumptions.

8. The instrument used to measure attitudes toward science was the Reaction Inventory, Attitudes Toward Science and Scientific Careers. It was a 93-item inventory in which statements were limited to the following five categories:

a. Science's Impact on Society.

b. Society's Impact on Science.

c. The Scientist.

d. Scientific Work.

e. The Nature of Science.

Importance of the Study

In 1962 two of the four public high schools in Tacoma selected the Chemical Education Material Study (CHEM Study) course-of-study as part of their curriculum offering in science. The following year the remaining two high schools also adopted this program. The CHEM Study personnel have stated, implied and assumed that a growth in critical thinking abilities and acquisition of positive attitudes was and is a paramount concern of the program. To date, this assumption has not been evaluated or validated in the Tacoma Public High Schools. Studies related to this problem are meager and inconclusive. The objectives of growth in critical thinking abilities and positive changes of attitudes toward science have been accepted rather than evaluated.

The Fifty-Ninth Yearbook of the National Society for the Study of Education has identified the important objectives of science which include (79, p. 185):

> Inculcating higher virtues such as accuracy, critical thinking, scientific honesty, and more generally, scientific method.

Teaching for attitudes is also stressed as an important objective in the teaching of science. Further support of these objectives is found in the Thirty-First and Forty-Sixth Yearbooks of the National Society for the Study of Education (77, 78). In the National Science Teachers Association booklet entitled Theory Into Action is found (75, p. 8):

> The strategies of learning must be related to the conditions that will lead to an understanding of the conceptual structures of science and of the modes of scientific inquiry.
>
> One of the first tasks in teaching science is to teach the inquiry process of science. By means of extensive experience in inquiry the student learns to place objects and events in categories and classes. He establishes a conceptual framework. This conceptual framework, in turn, focuses his attention on other phenomena, and helps him build new categories which are more comprehensive or more abstract. The conceptual scheme ties past experience to the present and serves as a guide for the comprehension and assimilation of new facts and concepts. It serves as a basis of what will happen in a new problem or situation.

While critical thinking was not definitely stated in the aforementioned, it was distinctly implied. This is evidenced by examining the definition of critical thinking as found in The Journal of Research in Science Teaching (91, p. 4). The definition was given as:

> Critical thinking is the kind of thinking characteristically used by scientists in solving problems. It involves defining problems, hypothesizing, recognizing assumptions, procuring, testing, and evaluating evidence, generalizing and applying generalizations and principles.

One seldom reads a text in science education without encountering attitudes toward science and critical thinking abilities as basic objectives in the teaching of science. This is seen in the publications of Brandwein, Richardson, Burnett, Hurd, and many others. The authors emphasize the need for teaching critical thinking abilities and developing and fostering positive attitudes toward science.

In discussion objectives, Richardson stated (85, p. 8-9):

> The science teacher should teach in such ways that the student will.... develop the ability to think critically, to use the methods of science effectively.

Burnett further discussed the outcome of critical thinking and added (22, p. 20-24):

> Critical thinking. We must develop abilities that will enable our students to engage, throughout their lives, in the process of self-education and in the judicious and critical use of facts for the betterment of their personal lots and the lot of mankind.

Aylesworth in his pamphlet Planning for Effective Science Teaching discussed the skill of critical thinking and the reasons for evaluating objectives (6, p. 79):

> It would seem reasonable that we evaluate students and their accomplishments in the light of the objectives that we set down for them - knowledge, skills, and attitudes. We must face the fact that we do teach skills and attitudes, whether we want to teach them or not. Students will always develop skills or attitudes in or towards the class. It is up to us to be sure that the skills they gain are desirable skills and the attitudes they develop are proper attitudes.

Aylesworth further discussed appreciating science as including positive attitudes. Planning for effective science teaching involves an appreciation for science. He concluded, to appreciate science (6, p. 43-47):

> ...that is, to be aware of the values of science, requires positive attitudes toward science. Based partly on the assumption that 'to know science is to love science,' this idea forces us to the conclusion that we must foster scientific attitudes in order to foster appreciation for science.
>
> ...we must look at the ways in which human beings form attitudes and appreciations. People form attitudes after having pleasant or unpleasant experiences. Another way people form habits is by absorbing them from other people. A third way in which we learn an attitude is through an impressive experience. Finally, we develop attitudes through a build up of many experiences.
>
> We must, therefore, concentrate on building up an accumulation of favorable impressions that can be developed into proper attitudes and appreciations in the field of science.

Building up these favorable impressions alone is not enough. One should also evaluate the extent to which attitudes and appreciations are being learned or absorbed.

More attention has increasingly been given to teaching critical thinking abilities and developing positive attitudes toward science. To teach for these objectives, one must plan adequately and incorporate these aims directly into the methods of teaching with subsequent evaluation of the goals to determine if they have been attained to some greater or lesser degree.

The Tacoma Public Schools presumes to meet the objectives of growth in critical thinking abilities and positive changes in attitudes toward science as an objective of the chemistry course-of-study in the curriculum. The Chemical Education Material Study program presumes to meet these objectives. The basic problem for this investigation was the extent to which the Chemical Education Material Study course-of-study in the Tacoma High Schools met these objectives.

Objectives are not merely stated goals. They are directions for teaching and learning. The results of teaching should be noted in the behavioral changes within and without the student. The need for and the importance of this study was to evaluate the growth in critical thinking abilities and attitudes toward science and to compare the students in chemistry to comparable students not enrolled in chemistry. It was the purpose of this study to attempt specifically to determine whether or not changes in critical thinking abilities and attitudes toward science were related to a specific course, the Chemical Education Material Study course. By so doing, the investigation provided information as to the amount of growth in critical thinking ability and positive changes in attitudes toward science that were developed and fostered by the Chemical Education Material Study course-of-study.

CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

Hopefully, a curriculum is a well thought out arrangement of learning experiences. It is a developed tangible sequence of many facets of teaching and learning and is usually produced through a plan of development. Curriculum development involves four important phases which include:

1. The selection of objectives.
2. The determination of content to meet those objectives.
3. The selection of the best teaching methods.
4. The program for evaluation of the objectives.

Of prime importance in the development of a curriculum is the selection of objectives. It is the first step in curricular design and aids in determining the goals students should realize. Objectives help to establish a framework for the selection of subject matter to be used and the methods to be employed. Without aims in education, learning becomes rather "hit or miss" and lacks careful consideration.

Having objectives alone is not enough. If objectives are established, planned, and used, then a method should be employed to determine the extent to which these objectives have been met. Aylesworth stated (6, p. 79):

> It would seem reasonable that we evaluate students and their accomplishments in the light of the objectives that we set down for them - knowledge, skills, and attitudes. We must face the fact that we do teach skills and attitudes, whether we want to teach them or not. Students will always develop skills or attitudes in or towards a class. It is up to us to be sure that the skills they gain are desirable skills and the attitudes they develop are proper attitudes.

Objectives of Science Education

Since the *Thirty-First Yearbook of the National Society for the Study of Education* more importance has been stressed upon the role of science education and the development of the objectives of science education. This yearbook was one of the first concrete attempts to determine the patterns of science education in the United States.

The *Fifty-Ninth Yearbook of the National Society for the Study of Education* identified the important objectives of science which included (79, p. 185):

> Inculcating higher virtues such as accuracy, critical thinking, scientific honesty, and more generally, scientific method.

Teaching for attitudes was also considered as an objective in science teaching. The aforementioned objectives are also found in the *Forty-Sixth Yearbook of the National Society for the Study of Education.*

In *Science Education in American Schools,* Part I of the

Forty-Sixth Yearbook of the National Society for the Study of Education, the primary objectives of science education were identified as (79, p. 28-29):

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

Nelson (78, p. 20-20) grouped these objectives into three divisions:

1. Knowledge;
2. Intellectual Abilities and Skills; and
3. The Affective Domain.

In 1961 the National Science Teachers Association listed the following as long range objectives for science education (95, p. 28):

1. As a result of science education, students should habitually and skillfully employ sound thinking habits in meeting problem situations.

2. Students must acquire a working concept of the relations between science and society, science and individuals, and science and technology.

3. They should not only carry on sound thinking, they should have a fund of reliable knowledge with which to think.

Hurd stated in Rethinking Science Education (79, p. 33) that the objectives of science education have changed little in the past 25 years. He also listed the following as some objectives that could be used for making curricular development (79, p. 33-37):

1. Problem-solving. A process of inquiry involves careful observing, seeking the most reliable data, and then using the rational processes to give order to the data and to suggest possible conclusions or further research.

2. Attitudes. The knowledge and methods of science are of little importance if there is no disposition to use them appropriately. Open-mindedness, a desire for accurate knowledge, confidence in the procedures for seeking knowledge and the expectation that the solution of problems will come through the use of verified knowledge, these are among the "scientific attitudes".

   To understand the scientist is also to understand some of his attitudes, such as the desire to know and to discover, a curiousity about the world, the excitement of discovery, and the desire to be creative.

3. Abilities. Young people need to acquire those skills and abilities which will enable them to assume responsibility for expanding their own learning. Some of these are:

   a. Locating authoritative sources of science information.

   b. Making valid inferences and predictions from data.

   c. Recognizing and evaluating assumptions.

   d. Recognizing the pertinency and adequacy of data.

   e. Seeking new relationships and ideas from known facts and concepts.

To support Hurd's inference that objectives have changed little in the past 25 years is seen in the report, Education for All American

Youth by the Educational Policies Commission of the National Education Association in 1944. This commission was concerned with redirecting science education and identified science as an integral aspect in the education of youth. Attitudes and appreciations of science were to be stressed through social problems. The outcomes expected from the teaching of science were stated as follows (60, p. 133):

1. An educated person will understand that science is based upon methods which man must slowly and painstakingly develop for discovering, verifying, interpreting, and organizing the facts of the world in which we live and about the people in it.

2. He will know that the use of scientific methods has made revolutionary changes in man's way of living and thinking.

3. He will know that scientific advances have depended upon precise measurement and accurate calculations.

4. He will recognize that problems in human society as well as in the physical world should be attacked by scientific methods and a scientific point of view.

5. He will be familiar with certain fundamental principles and facts from the sciences, which when taken together, gives him a sound view of the nature of the world in which we live.

Evaluation of the above objectives indicated three definite areas:

1. Problem-solving;

2. Attitudes;

3. Skills and Abilities.

In the National Science Teachers Association booklet entitled

Theory Into Action is found (75, p. 32):

> The strategies of learning must be related to the conditions that will lead to an understanding of the conceptual structures of science and of the modes of scientific inquiry.
>
> One of the first tasks in teaching science is to teach the inquiry process of science. By means of extensive experiences in inquiry the student learns to place objects and events in categories and classes. He establishes a conceptual framework. This conceptual framework, in turn, focuses his attention on other phenomena and helps him build new categories which are more comprehensive or more abstract. The conceptual scheme ties past experience to the present and serves as a guide for the comprehension and assimilation of new facts and concepts. It serves as a basis for prediction of what will happen in a new problem or situation.

In its report Science and Public Policy, the President's Scientific Research Board expressed its opinion that students should gain an understanding of (60, p. 91):

> (1) The methods of science;
>
> (2) the influence of science upon human life and thought;
>
> (3) the facts and principles essential to an understanding of themselves and their environment; and
>
> (4) an appreciation of the scientific enterprise.

The American Association for the Advancement of Science established a Commission of Science in 1963. The objectives formulated by this commission were summarized by Kessen as (65, p. 4-6):

> 1. Science as inquiry. Science is best taught as a procedure of inquiry. It is a structured and directed way of asking and answering questions.

2. The scientific attitude. The discipline of scientific inquiry demands respect for the work of the past together with a willingness to question the claims of authority. The attitude of intelligent caution, the restrain of committment, the belief that difficult problems are always susceptible to scientific analysis, the courage to maintain doubt... will be learned through inquiry.

3. The processes of science. The statement of a problem... ability to recognize and use sources of reliable information... ability to observe... comparison of phenomena... and ability to evaluate evidence and draw conclusions... should be developed.

4. Scientific knowledge. A knowledge of the basic findings about the universe, the structure and reactions of matter, the conservation and transformation of energy, the interaction of living things and their environment... give boundaries and direction to scientific inquiry.

Many outstanding authors in the field of science education have listed objectives for the teaching of science. This list includes the objectives referred to previously in this chapter and Richardson added (85, p. 8-9):

> The science teacher should teach in such ways that the student will... develop the ability to think critically, to use the methods of science effectively.

Burnett also listed objectives for science education and remarked (22, p. 20-24):

1. To relate science to the progressive refinement of the democratic way of life... The over-all responsibility of science teachers in a great democracy is therefore to challenge, stimulate, guide, and assist young people to develop the understandings, critical abilities, attitudes, and viewpoints that represent the best in the scientific and democratic traditions.

2. We must wisely select and soundly organize the content and experiences of our instruction so that facts, principles, and broad understandings that are fundamental to sound human living in the modern world will be learned--really learned--and retained.

3. Critical thinking. We must develop abilities that will enable our students to engage, throughout their lives, in the process of self-education and in the judicious and critical use of facts for the betterment of their personal lots and the lot of mankind.

McGrath remarked in Science and General Education (73, p. 9) that to show what science is like, and what scientists are like are the most important things we can expect from a science course. He also stated (73, p. 7) that we should encourage a scientific attitude and critical thinking in general life.

Cohen listed the following as some of the important objectives in the teaching of science (26, p. 32-33):

1. To provide enough understanding to enable the educated citizens to collaborate intelligently with those who are actively engaged in scientific pursuits.

2. To enable the citizen both to criticize and to appreciate the effects of the sciences on his society.

3. To provide our students with rich and various experiences of independent thinking and critical attitudes.

Summary

Many objectives related to science education have been discussed. While each author or commission has presented their lists or views of objectives some general consensus is noted. These objectives could be summarized as:

1. To demonstrate attitudes which indicate an understanding of the nature of science and scientists.
2. To show evidence of the ability to think critically, to evaluate the facts of science, and to apply these to daily living.
3. To recognize the role of science in a modern and complex society.
4. To demonstrate a knowledge and understanding of the basic scientific facts, principles, and concepts.

Studies Related to Critical Thinking

Teaching students to think is an often expressed goal in education. Authors such as Dressel (36), Dale (33), Edwards (40), Burton, Kimball, and Wing (23) and others have listed this objective as a primary goal in teaching. Burnett (22) and Richardson (85) have specifically listed critical thinking ability as an outcome of science education.

Many studies have been conducted related to critical thinking abilities. To assist in reviewing the information, research can be classified into three basic categories:

1. The nature of critical thinking.

2. The teachability of critical thinking.

3. Methods of instruction related to critical thinking abilities.

The Nature of Critical Thinking

In discussing critical thinking as an objective of many studies and investigations, Edwards stated (40, p. 269-270):

> The teaching of critical thinking in the schools is established as an objective by means of an authoritative, dogmatic statement. Accepting this objective there are many teachers who try hard to improve the critical thinking ability of their pupils. They are not content to assume that proof of the acquisition of knowledge is also proof that such knowledge will be rightly used.
>
> It appears that ability to do critical thinking is a valid objective of the schools in that it is possible to isolate techniques of critical thinking and test for the acquisition of skill in the use of these techniques.
>
> On the other hand, if pupils are to be taught to think they must first be given something to think about. Thinking is possible only with familiar concepts for most people. Pupils will not, in general, be able to think about materials to which they have been merely exposed.

Dressel and Mayhew in analysis of research have defined critical thinking by referring to five abilities (37, p. 179):

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 the validity of inference.

Research points to the notion that students in the secondary schools are able to gain in critical thinking ability when they have experiences that are specifically designed for improving these abilities. Burton, Kimball, and Wing (23, p. 256) have supported this contention by indicating that abstract and inductive capacities mature most rapidly during the period of adolescence.

Many factors seem to be related to critical thinking abilities. The Watson-Glaser Critical Thinking Appraisal has been found to have a correlation of .48 to .68 (103, p. 9-11) to several intelligence tests. Teichman (97, p. 268-279) in a study of high school students concluded that intelligence was related to the ability to reach conclusions on items in science. In another study, Alpern (3, p. 220-226) found a positive correlation between intelligence quotient and the ability of high school students to devise or choose tests of scientific hypotheses. On the other hand, Sorenson (94) obtained evidence that there was no relationship between a student's mental ability and change in critical thinking ability. He concluded from his study that mental ability was not directly related to change in critical thinking ability based on the results of the Watson-Glaser Critical Thinking Appraisal and the Cornell Critical Thinking Test.

Dressel and Mayhew (37, p. 56-58) found that grades in general education classes were positively correlated to scores on the American Council on Education Test of Critical Thinking at approximately the same magnitude as tests of intelligence.

In discussing the nature of critical thinking as part of his investigations, Fox remarked (48, p. 357):

> Procedures which were reported to be most difficult to use require higher levels of critical thinking on the part of the students - to analyze, interpret, and evaluate information; and to determine the most reasonable and logical conclusions. The procedures which were reported to be the least difficult to use are the procedures for gathering information, and most of them require only a passive type of thinking or learning on the part of the students - to gain information from audio-visual aids, to gain information by listening to others. This does not mean that such activities are without value, on the contrary, they are essential procedures for developing skill in critical thinking and for solving problems. However, they are only preliminary steps in critical thinking, not ends in themselves.

In still another study, Kopans (67) noted that the more complex abilities such as critical thinking are developed slowly. He analyzed the relationship between natural science specialization and social science in college with respect to ability in critical thinking. Selected items from the Watson-Glaser Critical Thinking Appraisal were used and when students were controlled by age and intelligence the social science majors showed significant differences in critical thinking only on the controversial items on the appraisal form. In other aspects, no significant differences were noted.

Studies by Alpern (3) and Furst (49) tend to support the possiblity that students have a general critical thinking ability in much the same manner as they have a general intellectual ability. They concluded this on the basis of positive correlations between general intelligence and certain thinking skills.

The Teachability of Critical Thinking

Investigations by Thalen in science and Fawcett in mathematics as reviewed by Edwards (40) concluded that pupils can be taught to think critically about problems if the various subjects are planned thoroughly to meet this objective.

Dressel and Mayhew (37, p. 390-391) in investigating college teaching noted that institutions that had special courses in critical thinking had no distinct advantage over other colleges or universities. These researchers found that only small gains were found when only one course was aimed towards teaching critical thinking. They further found that the greatest gain in critical thinking occurred during the freshman year in college. Higher gains were observed when an entire curriculum was devoted to developing critical thinking abilities. The largest increases were seen in those institutions that had a thoroughly organized educational curriculum for the freshman year. Dressel and Mayhew (37) concluded that the objective of critical thinking was frequently not met because the activities involved a reading or studying about the thinking of others. In other words, definite activities were not planned to foster the growth of critical thinking abilities. General learning activities were used as modes of developing critical thinking skills.

Herber (57) studied the results of high school students' critical thinking abilities when controlled according to sex, grade, and course. When special materials designed to improve critical thinking were used regularly in the course, the experimental group showed an increase in critical thinking ability. In a research involving social studies students, Chenowith (25) concluded that students who studied materials designed to develop reflective thinking showed significant gains in these abilities over controlled groups. Edwards (40) found that chemistry students in an experimental group showed significant gains over control groups when they had been exposed to activities designed to develop critical thinking abilities.

In a study of scientific thinking in a college biological science course, Mason concluded the following (72, p. 283):

1. The telling method of teaching can be an effective method for teaching students factual information.

2. Ability to think scientifically can be a concomitant outcome of science education.

3. Ability to think scientifically can be taught more effectively when the students are given direct training in the methods of science than when they do not receive such training.

4. Problem-solving can be an effective method for teaching both facts and skills inherent in the methods of science.

In discussing the objectives of developing critical thinking based on related studies Glaser remarked (52, p. 418):

> Such evidence as there is points to the development of critical thinking as a long term task in which but small gains will be shown for any particular course. It is, therefore, of the utmost importance that fostering the ability to think critically becomes the aim of all teachers for the entire period of a student's schooling. . . Critical thinking, then, is evidently the deserved integrating principle or goal of education in the achievement which promises that there will be a lifelong interest in learning.

From the studies cited, it appears that critical thinking abilities can be taught. To do so, however, requires careful planning of activities to develop this expressed objective. Critical thinking is not a residue of an educational curriculum but is rather an essential, well thought out objective with specific and determined activities necessary to attain this goal.

Methods of Instruction

Using a pre-test and post-test design Howe (58) studied biology teaching in Oregon. Positive gains were noted in critical thinking as measured by the Watson-Glaser Critical Thinking Appraisal in 44 of 51 biology classes studied. Classes involving the use of problem-solving techniques with instruction in critical thinking showed the greatest gain during the time period.

Yudin (108) found no gains in the development of critical thinking in college freshmen when he compared two methods of instruction. Even though the program was designed to improve critical thinking, no significant gains were noted in the experimental group.

Kastrinos (62) investigated two methods of teaching with respect to development in critical thinking. He compared a textbook-recitation method with a principles-critical thinking method of instruction in high school biology. The Watson-Glaser Critical Thinking Appraisal was utilized in a pre-test and post-test design. Kastrinos (62, p. 2251-2252) indicated that critical thinking abilities can be improved over a one semester period. The classes using textbook-recitation method did not show gains over the principles-critical thinking group in any respect that was examined in the investigation.

In an investigation comparing students with "open" belief systems and "closed" belief systems, Kemp (64) found that students with the "open" approach progressed better in critical thinking ability than those with the "closed" system. He further concluded that improvement in critical thinking skills was greatest when small groups of students were involved and directed instruction used with these students.

Sorenson (94) studied the changes in critical thinking between students in a laboratory-centered and lecture-demonstration patterns of instruction in high school biology. He concluded that students in the laboratory-centered pattern of instruction showed significant gains in critical thinking for all levels of intelligence based on the _Cornell Critical Thinking Test_ and the _Watson-Glaser Critical Thinking Appraisal_. Evidence was also obtained to indicate that there was no relationship between a student's mental ability and change in critical thinking ability.

Henderson (56) conducted a study on the teaching of logical and critical thinking involving approximately 1500 students in various classes in high school. Special instruction in critical thinking were employed. Using the _Watson-Glaser Critical Thinking Appraisal_ significant gains were made in favor of the experimental classes. However, gains on the _American Council on Education Test of Critical Thinking_ were not significant.

Rickert (86) noted that in an experimental physical science course in which attempts were made to analyze problems, examine assumptions, collect and organize data, and to test hypotheses greater gains were made by the experimental group on the _American Council on Education Test of Critical Thinking_ than by the regular physical science courses. The results were based on a one semester time interval.

In a review of several studies in science education, Hurd (60) discussed an investigation completed by Weisman. In this study, Weisman noted that students could be taught critical thinking skills if the course were organized around problems and problem-solving activities.

In an investigation involving seven United States History teachers Wallen (101) found that an experimental group showed greater gains on an Induction, Deduction, Semantics Critical Thinking Test designed by Ennis (42) than did students in regular history classes. Curricular changes were used over a three week unit in critical thinking as part of the instruction for the experimental group. It should be noted, however, that there were no significant differences in gains between the control and experimental groups using the Watson-Glaser Critical Thinking Appraisal.

Graham (54) investigated the effectiveness of teacher-centered and student-centered classes regarding changes in critical thinking abilities. Students were matched using scores on the Otis Mental Ability Test and the Watson-Glaser Critical Thinking Apprisal as pre-tests. Greater gains were shown by the experimental group over the control group taught by the same instructor.

Crall (29) studied high school biology students using a control and an experimental group. The experimental class was instructed in learning and applying procedures which required the students to use and apply principles. Student growth was measured by written tests and observation. Both the control and experimental group showed gains in critical thinking skills. In his conclusion Crall noted that a direct method of instruction produced better gains in critical thinking skills.

Dressel and Mayhew (37) studied the growth in critical thinking that was affected by teacher modification techniques. They found that gains were sometimes less in experimental classes than in regular classes where little or no attempt was made with respect to developing critical thinking skills. Dressel and Mayhew concluded (37, p. 285):

> ... minor changes in techniques imposed upon a course where the major emphasis remains on coverage of content are inadequate as a solution to this problem.

Lee (68) studied the effect of two methods of teaching high school chemistry upon critical thinking abilities. The control group followed a conventional pattern of instruction while the experimental group engaged in problem-solving activities. After an 11 week instruction period and using a post-test design only, Lee found that there were no significant changes in critical thinking abilities for either the control or experimental group. The results were based on the Watson-Glaser Critical Thinking Appraisal. The lower ability students in the experimental group showed a difference at the .10 level in the investigation. In conclusion, Lee stated (68, p. 4579):

> The kind of materials the students use, the extent to which individual initiative is permitted, the amount of meaningful and significant problem-solving in which

> the students engage, and the ability of the teacher to lead students to self-discovery will all contribute to the effectiveness of teaching for critical thinking.

In a comparative study of Chemical Education Material Study and traditional chemistry, Anderson (5) found no significant differences in the cognitive processes between the two groups based on the Watson-Glaser Critical Thinking Appraisal. While the Chemical Education Material Study students scored higher on the instrument, no significant differences were noted.

The aforementioned studies have indicated that critical thinking abilities can be developed when teaching procedures and specific materials are used. If the objectives are well planned, growth in critical thinking can be obtained. It should also be noted that these studies have indicated that different critical thinking tests appear to measure various and different aspects of critical thinking. The investigations noted in this study provide some evidence that critical thinking abilities can be taught and developed if proper planning and adequate learning activities have transpired.

The nature of research done to date in critical thinking has been summarized by Dressel and Mayhew where they state (37, p. 180-181):

> Much of the research accomplished to data has been divorced from teaching practice. In this same connection, there is a noticeable lack of suggestions and evidence as to how critical thinking can be taught.

Still one further weakness in critical thinking research lies in the fact that the way it is presented too often suggests that emphasizing critical thinking can be a mechanical sort of operation tacked onto some particular college course.

Having pointed out the lack of adequate research to date, we are constrained to advance some ideas which we believe might be fruitful in the area of critical thinking. Perhaps the first step in the development of major research in this area is for teachers to become concerned about the development of thinking on the part of their students. So long as teachers are unaware or unconcerned about the apparent fact that imparting information by means of class lectures or reading textbooks is relatively ineffective in the development of the higher mental processes, the importance of research in connection with critical thinking is likely to be overlooked.

To fulfill the major need of research in connection with critical thinking, it is essential for such research to be basically oriented toward and integrally related to classroom practice.

Studies Related to Attitudes Toward Science

The development of positive attitudes toward science has been frequently listed as an objective in science education. While this objective is often stated, it has been studied only sparingly. Few investigations pertaining to attitudes toward science have been conducted. The investigations completed to date have related primarily to instruments produced by the researcher and are often limited to only certain aspects of attitudes toward science and related areas.

One of the most outstanding and detailed investigations in scientific attitudes has been that of Allen (1, 2). In 1957 he conducted a study of high school seniors to measure their attitudes toward science and scientific careers. A 93 item reaction inventory was constructed by Allen and given to the seniors. The study was designed to determine if high school seniors who chose scientific careers had more positive attitudes than those choosing non-science careers. It was further designed to determine if there was a difference in attitudes toward science between high ability students who chose scientific careers and those who chose non-science careers.

Allen concluded that the high school seniors generally had positive attitudes toward science. Analysis further indicated a relationship between intelligence and positive attitudes toward science and the scientific enterprise. The item analysis of the instrument indicated that the image of the scientist was not quite exact and the seniors appeared to show a lack of understanding related to the scientist. Allen also concluded that the teacher was the most important factor in developing positive attitudes toward science and the scientific enterprise.

In 1959 Allen (2) made a follow-up study of the same groups of students. He designed a questionnaire containing 29 statements from the original instrument that discriminated at the .01 or .05 confidence level. While using only a sample of his original population, Allen found that attitudes had changed quite noticeably. More positive attitudes had developed towards the scientist and his work and toward the nature of the scientific enterprise.

Howe (58) in a study of biology students in Oregon employed a modified instrument of Allen's reaction inventory. He standardized the responses by submitting the reaction inventory to professors of science at Oregon State University. The study disclosed that 40 of the 51 classes studied showed favorable changes in attitudes using a pre-test - post-test design. Evidence was further obtained which indicated that students' attitudes changed in the direction of the attitudes held by the classroom teacher in most of the classes.

Wilson (107) investigated the attitudes and opinions of high school and college students related to certain facets of science and its place in our society. Statements were submitted to several groups of students and they were requested to indicate agreement or disagreement with the items. The responses of the students indicated a uniformity in their attitudes and opinions. The groups tended to view science as being technologically oriented and agreed that scientists were more logical in their work than are other professionals. Wilson further concluded that the responses of the students showed a lack of understanding toward science and its place in our society.

Belt (15) investigated the attitudes toward science and scientists by use of a test of factual items designed to measure the accuracy of perception of science and scientists. He noted that high school pupils showed a favorable attitude toward science and scientists and that high ability students had more favorable attitudes than did representative cross sections of high school students.

Barber and Hirsh (8) listed studies related to attitudes toward science. Investigations of Mead (8) and Beardslee(8) showed that students generally showed favorable attitudes toward science but had a reticence toward selection of science as a career.

While the research involving attitudes toward science has been meager, there are some general implications to be noted. The studies noted have indicated that attitudes toward science are generally favorable in science classes and particularly so when attempts are made to foster positive attitudes as part of the instructional pattern. The investigations infer that attitudes should be taught and not left to circumstantial teaching. Favorable attitudes are essential to an understanding and appreciation of science.

Summary

Studies pertaining to critical thinking have noted that critical thinking is a complex and variable ability. It can be thought of as having certain components such as deduction, assumption finding, inference, etc. While being a complex pattern, critical thinking abilities can be taught if proper instruction is provided. Different methods produce growth in critical thinking if concrete attempts are made to include it as an objective in the teaching of science.

Attitudes toward science are an important objective in science education. Proper attitudes are essential for building an appreciation and an understanding of science. Instruments have been developed to determine the extent to which attitudes are being acquired.

The review of the literature has indicated that the study proposed in this investigation is a reasonable one. The studies noted have addressed themselves to the general problem and support the reason for testing the main hypothesis of the dissertation.

CHAPTER III

DESIGN OF THE STUDY

The purpose of this investigation was to compare the growth in critical thinking abilities and changes in attitudes toward science and scientific careers between chemistry and non-chemistry students. The basic hypothesis of the investigator was that chemistry students would show greater gains in growth in critical thinking abilities and change in attitudes toward science and scientific careers than the non-chemistry students. Factors such as academic ability and academic achievement based on certain test scores and grade point average were further hypothesized to be a function of the students' critical thinking abilities and attitudes toward science and scientific careers. The design utilized in this study was for the purpose of testing the null hypotheses indicated in Chapter I using an analysis of covariance for academic ability and academic achievement based on certain test scores and grade point averages.

The Experimental Design

The purpose of this investigation was to compare the growth in critical thinking abilities and changes in attitudes toward science and scientific careers between chemistry and non-chemistry students. Since growth and change were indicated, a pre-test - post-test design seemed the most logical experimental design for the study. It was necessary to assess the critical thinking ability and the attitudes toward science before the instruction occurred to determine the extent to which the course contributed to these objectives.

Gage (50, p. 178) referred to this design as one of the True Experimental Designs and indicated it as:

R_1	O_1O_2	X	O_1O_2
R_2	O_1O_2		O_1O_2

where:

R_1 represents the random selection of chemistry students

R_2 represents the random selection of non-chemistry students

O_1 represents the test of critical thinking ability the <u>Cornell Critical Thinking Test, Form X</u>

O_2 represents the attitudes toward science scale, <u>Reaction Inventory, Attitudes Toward Science and Scientific Careers</u>

X represents the variable, in this investigation, the Chemical Education Material Study course.

The sources of internal validity such as (50, p. 178):

History

Maturation

Testing

Instrumentation

Regression

Mortality

Interaction of Selection and Maturation

are all controlled by this design.

The factors of critical thinking abilities and attitudes toward science and scientific careers are those things which affect criterion scores and were controlled in this study through covariance techniques. This satisfies the pre-test - post-test control design as described by Gage (50, p. 178).

Selected Instruments

Reaction Inventory, Attitudes Toward Science and Scientific Careers

Attitudes held by the students were obtained by responses to the Reaction Inventory, Attitudes Toward Science and Scientific Careers used with the permission of the author, Hugh J. Allen, Jr. The scale was administered in September, 1966 and in March, 1967 using a pre-test - post-test design for analysis. The instrument was designed by Hugh J. Allen, Jr., and modified by Howe (58). The 93 item revision of Howe was used in this investigation.

Allen (1) constructed the attitude scale by analysis of current literature regarding science and scientific discoveries. He noted contradictory and derogatory comments found in the literature. From this start, Allen interviewed scientists and in turn developed the inventory. It consisted of 95 items which were categorized into the following areas (1, p. 7):

1. Science's Impact on Society;
2. Society's Impact on Science;
3. The Scientist;
4. Scientific Work; and
5. The Nature of Science.

The instrument was administered to a group of scientists to obtain the "expected" outcomes to the items. The scores of the scientists were used to compare the student responses to determine the favorableness of the attitude held by the students. Howe further refined the process of scoring and submitted a 93 item inventory to a selected group of scientists at Oregon State University. Average scores were computed for each item to the nearest hundreth. The means of the responses are listed on Table 1. For the purpose of this study, Howe's modification was used.

Using a separate answer sheet and a reusable test booklet the students answered each item by using the following scale:

AA - complete agreement with the item

A - partial agreement with the item

Table 1. Means of scientists' responses to statements in Attitudes Toward Science and Scientific Careers.

Item Number	Mean	Item Number	Mean	Item Number	Mean	Item Number	Mean
1	1.53	25	3.82	48	2.77	71	3.18
2	.47	26	1.53	49	1.29	72	2.59
3	3.29	27	3.53	50	3.77	73	3.82
4	1.00	28	3.41	51	.77	74	3.94
5	2.00	29	2.71	52	3.00	75	3.71
6	.18	30	2.59	53	1.18	76	3.53
7	1.18	31	3.82	54	2.24	77	2.82
8	2.24	32	3.47	55	3.71	78	.41
9	.77	33	3.71	56	1.35	79	3.77
10	.29	34	2.06	57	3.06	80	3.77
11	2.00	35	.53	58	3.94	81	1.35
12	.77	36	3.71	59	3.71	82	3.53
13	2.71	37	1.24	60	.18	83	.24
14	3.94	38	1.82	61	1.18	84	3.18
15	2.59	39	.41	62	2.00	85	.24
16	1.18	40	1.59	63	2.35	86	1.47
17	.18	41	3.77	64	.18	87	1.47
18	.29	42	1.18	65	.82	88	3.59
19	2.53	43	.29	66	1.59	89	3.29
20	3.29	44	1.71	67	3.71	90	.53
21	2.06	45	2.24	68	3.47	91	.71
22	2.47	46	3.00	69	.18	92	1.53
23	3.29	47	1.53	70	.41	93	.59
24	.97						

N - neutral

D - partial disagreement with the item

DD - complete disagreement with the item

For the purpose of evaluation, point values were assigned on the following basis:

AA - 0 points

A - 1 point

N - 2 points

D - 3 points

DD - 4 points

If a student failed to answer an item, it was considered to be a neutral item and was scored 2 points. Only two students were unable to complete the inventory in the time alloted.

Cornell Critical Thinking Test, Form X

To assess the students' critical thinking abilities, the Cornell Critical Thinking Test, Form X was employed. It was administered in September, 1966 and in March, 1967 using a pre-test - post-test design for analysis. The test was divided into four sections:

1. Induction - 23 items
2. Reliability - 24 items
3. Deduction - 14 items
4. Assumption Finding - 10 items

The test was used with the permission of the author, Ennis, and was a 50 minute test. Three students did not complete the test in the alloted time. Separate answer sheets were provided with reusable test booklets. The maximum score possible on the test was 71, the minimum score was -35. The test was scored using the formula:

Score = Right - Wrong/2

The author of the test, Ennis, defined critical thinking as (45, p. 599):

> As a root notion, critical thinking is here taken to mean the correct assessing of statements. . . if we set about to find out what a statement means to determine whether to accept or reject it, we would be engaged in thinking, which, for lack of a better term, we shall call critical thinking.
>
> A critical thinker is characterized by proficiency in judging whether:
>
> 1. A statement follows from the premises,
> 2. Something is an assumption,
> 3. An observation statement is reliable,
> 4. A simpler generalization is warranted,
> 5. A theory is warranted,
> 6. An argument depended on an ambiguity,
> 7. An alleged authority is reliable.

This definition by Ennis finds strong support from such authors as Dressel (36), Dressel and Mayhew (37), Hurd, (59), Rust (89), and Watson (103). While they do not openly state this agreement, consistency is definitely found in the concepts they profess regarding the nature of critical thinking. Because of this agreement noted, the investigator selected the Cornell Critical Thinking Test, Form X, constructed by Ennis, as the desired instrument to measure the critical thinking abilities of the students in the investigation.

The Cornell Critical Thinking Test, Form X was originally administered to seventh and eighth grade students in "Central School A" (somewhere in Central New York state). Statistical data were derived from the 1,109 eighth grade students tested. The split half reliability estimates for the instrument was found to be .85. The split half reliability estimates for each of the four sections were (42, p. 28):

Induction	.85
Reliability	.77
Deduction	.60
Assumption Finding	.26

The information above indicates that there is a general acceptable level of reliability for the instrument, particularly the .85 value for the entire instrument.

Correlation of the critical thinking test with other known instruments are as listed (42, p. 29):

California Test of Mental Ability, Form S	.49
Total Intelligence Quotient	.49
Language	.59
Non-language	.35
The *Scholastic Aptitude Test* (SAT)	.49

The relatively low correlations strongly suggest that this critical thinking test measures thinking abilities different from those measured by mental ability and scholastic aptitude tests. Further support of this was found in Sorenson's investigation (94) noted in Chapter II of this investigation.

Criterion of Academic Achievement

The Numerical Ability score and the composite Verbal Reasoning, Numerical Ability score on the *Differential Aptitude Test* were used as controls of academic achievement. This test was administered to the sample population during the 1965-1966 (sophomore year) as part of the school district's basic testing program. Scores were available on all but 12 students (4 percent).

As a further indication of academic achievement the Background in Natural Science score on the *Iowa Test of Educational Development* was used. The test was administered during the 1964-1965 school year (freshman year) as part of the basic testing program. Scores were available on all but ten students (three percent).

The accumulative grade point average served as an indication of the students' academic achievement and was used as a control. The grade point average included all of the courses taken in grades nine and ten.

The test scores and grade point averages were taken from student records which served as the source of information for the students' academic achievement.

Criterion of Academic Ability

The total score on the School and College Ability Test was used as an indication of the student's academic ability. The test was administered to all juniors during October, 1966 as part of the basic testing program. The test scores were taken from student records which served as the source of information of the students academic ability. Scores were available on all but one student (less than one percent).

Selection of Sample

In order to determine the population all the eleventh grade mathematics classes in the Tacoma school district were surveyed. The names of the students were secured from class records. Each student submitted his schedule of classes so that the programs could be analyzed to determine the students taking the following courses:

Foreign language (German, French, Spanish or Latin)

Eleventh grade English

United States History

Eleventh grade mathematics

Chemistry (for the experimental group only)

The population totaled 861. There were 454 non-chemistry and 407 chemistry students in the original population.

This list was alphabetized into two lists, the chemistry and non-chemistry students, and the students were assigned a number progressively. The sample was drawn using Li's Table of Random Sampling Numbers (70, p. 589-598). A sample of 155 chemistry and 155 non-chemistry students was selected. On the first test, 153 chemistry and 149 non-chemistry students took the tests. On the second examination, 148 chemistry and 144 non-chemistry students took the examinations. The loss in numbers was insignificant within the investigation since a pre-test - post-test design was used. The internal validity was maintained due to the sample size and covariance controls.

The Sample Population

The purpose of this research design was to investigate the critical thinking abilities and changes in attitudes toward science and scientific careers of chemistry and non-chemistry students. The two groups were then compared in their abilities and attitudes. To review, chemistry students were defined as those students enrolled as of September, 1966 in the following courses:

Chemical Education Material Study Chemistry

United States History

Eleventh grade English

Eleventh grade mathematics

Foreign language (German, French, Spanish, or Latin)

The non-chemistry students were defined as those students enrolled as of September, 1966 in the following courses:

A non science elective

United States History

Eleventh grade English

Eleventh grade mathematics

Foreign language (German, French, Spanish or Latin)

The entire population of chemistry and non-chemistry students consisted of 302 persons; 153 chemistry and 149 non-chemistry students. The following Tables 2 and 3 indicate the male and female composition of the sample:

Table 2. Number and percentage by sex of chemistry students.

	Total Number	Male	Female
Number of Students	153	106	47
Percentage of Total (%)	100	69	31

Table 3. Number and percentage by sex of non-chemistry students.

	Total Number	Male	Female
Number of Students	149	102	47
Percentage of Total (%)	100	68	32

Both groups tended to have the same male-female ratio. The percentage of 66 for males is not unusual since it has long been recognized that more boys select eleventh grade mathematics than do girls.

The following test scores and criterion information were available from the school records as indication of student academic achievement:

1. The Numerical Ability score on the Differential Aptitude Test.
2. The composite Numerical Ability, Verbal Reasoning score on the Differential Aptitude Test.
3. The Background in Natural Science score on the Iowa Test of Educational Development.
4. The accumulative grade point average.

For the purpose of analysis and covariance controls, the students were grouped into the high and low subgroups based upon scores of the above four criteria. To determine the high subgroup and low subgroup, approximately one-third of the sample was placed in each subgroup based upon the ranking of the scores and the grade point averages.

Procedures Used in Collecting Data

Obtaining Test Scores

The *Cornell Critical Thinking Test, Form X* and the *Reaction Inventory, Attitudes Toward Science and Scientific Careers* were administered to the chemistry and non-chemistry students in September, 1966 and again in March, 1967. The tests were given to all eleventh grade mathematics students by class teachers, not by the investigator. Each teacher was given explicit instructions regarding the administration of the test so as to secure similar test conditions. The sample population test scores were sorted from the entire group scores. All the schools and classes in mathematics were tested within a three-day period in the September and March test situations.

The tests were administered according to directions provided on the test booklets. Students were given the opportunity to decline from taking the test in accordance with the wishes of the Tacoma School District. None of the students declined to take part in the investigation.

Obtaining Differential Aptitude Test, Iowa Test of Educational Development and School and College Ability Test Scores

The following scores were obtained from student records:

1. Numerical Ability score from the *Differential Aptitude Test* (1965)
2. The composite Numerical Ability, Verbal Reasoning score from the *Differential Aptitude Test* (1965)
3. The Background in Natural Science score from the *Iowa Test of Educational Development* (1964)
4. The total score from the *School and College Ability Test* (1966)

The year in which the tests were administered to the students is included in parenthesis. Scores were available on at least 96 percent of the students for each test.

Academic Records

The academic records of each student were examined and data compiled with reference to the accumulative grade point average. This average included the ninth and tenth grade subjects of the students and was based on the following point system:

A - 4 points

B - 3 points

C - 2 points

D - 1 point

E - 0 points

The grade point average was considered to be related to the academic achievement of the students.

Statistics Utilized in Analysis of Data

Chemistry and non-chemistry students in eleventh grade mathematics classes were evaluated during the 1966-1967 academic year with respect to critical thinking abilities and attitudes toward science and scientific careers.

Academic achievement was measured by the Numerical Ability and composite Numerical Ability, Verbal Reasoning score on the *Differential Aptitude Test*. It was further evaluated by the Background in Natural Science score on the *Iowa Test of Educational Development* and the accumulative grade point average of the student. The scores and grade point averages served as controls for student differences in academic achievement in the tests of null hypotheses indicated in Chapter I of the study.

Academic ability was measured by the total score on the *School and College Ability Test*. The score was used as a control for student differences in academic ability in tests of null hypotheses indicated in Chapter I of the study.

Determination of High and Low Subgroups

For purposes of evaluation, the students were grouped into high and low subgroups based upon selected scores on the Differential Aptitude Test, the Iowa Test of Educational Development, the School and College Ability Test, and the accumulative grade point average. The scores and grade point averages were listed in a highest to lowest order and approximately the high one-third and the low one-third were considered to be the high and low subgroup, respectively.

Each test score was listed in a descending order by number and scores were analyzed for the one-third grouping. The total population for each group, chemistry and non-chemistry, was divided by three to determine the one-third and the scores were counted. Due to the arrangement of scores, it was not possible to keep the numbers of students in each subgroup equal. For example, the score of 78 was held by 11 students. If 47 students were needed for the top one-third and the count of 43 was reached by the score 79, then the number of students possessing scores of 79 or higher were included in the high subgroup of the sample population. The actual number of persons in each group is indicated on Table 1.

Determination of Changes in Attitudes

Student attitudes were determined from responses to the

Reaction Inventory, Attitudes Toward Science and Scientific Careers given in September, 1966 and in March, 1967. Group means rather than individual scores on each item were used as the unit of analysis, since it was the group and not the individual who was involved in the chemistry, non-chemistry curriculum. Group means were calculated for each item and this was done by totaling the raw scores for the group and dividing by the number of students in each group.

Table 4. Number of persons in high and low subgroups based on selected test scores.

	Group			
	High		Low	
Test	Chemistry	Non-chemistry	Chemistry	Non-chemistry
Differential Aptitude Test Numerical Ability Score	42	48	48	44
Differential Aptitude Test Composite Score	52	47	52	49
Iowa Test of Educational Development Background in Natural Science Score	48	46	44	43
School and College Ability Test Total Score	46	43	47	43
Accumulative grade point average	50	47	48	46

A total difference between the attitudes of the students in each group and the scientists was obtained for both the September and March testing. The total difference was calculated by summing the item differences for each group. A total difference of 0 would indicate the students possessed attitudes corresponding to those of the scientists' means.

The changes in the attitudes held by the students were determined by comparing the September and March differences. If the total differences between the group and the scientists were smaller in March than in September, it was determined that the group had made a positive gain in attitudes toward science and scientific careers. If the total difference were larger in March than in September it was determined that the students had not made positive gains in attitudes toward science and scientific careers.

The t-test was computed on the September and March differences between the students' and scientists' means to determine if there were significant changes in attitudes toward science and scientific careers for each group. In the tests of the null hypotheses, means of the chemistry students were compared to means of the non-chemistry students. Since scores on such tests are usually correlated with academic achievement and academic ability, certain test scores and grade point averages were used as controls of covariance to attain a measure of control of individual differences.

Determination of Growth in Critical Thinking Abilities

Student critical thinking abilities were determined from scores on the Cornell Critical Thinking Test, Form X given in September, 1966 and in March, 1967. The total score for each student was computed by:

$$\text{Score} = \text{Right} - \text{Wrong}/2$$

To determine the gains in critical thinking abilities, the two scores were compared. A higher score on the March examination would indicate a gain in critical thinking ability.

Differences in student scores were computed for each student and the group means were analyzed for significant differences using the t-test. In the tests of null hypotheses, means of the chemistry students for each of the criterion were compared to the means of the non-chemistry students. Since scores on such tests are usually correlated with academic achievement and academic ability, certain test scores and grade point averages were used as controls of co-variance to attain a measure of control of individual differences.

Processing of the Data

Data from the various sources were tabulated on data cards, then punched on IBM cards for analysis. Using the pre-test -

post-test design noted in the previous sections, the investigator wrote, punched, and tested programs for execution on the IBM 1107 machine. Programs were designed to compute means, standard deviations, and the t-test of analysis used in this investigation.

These programs were computed at the Research Center of the Weyerhauser Timber Company using data cards. At least one calculation from the computer and a stack deck were checked on a desk calculator in order to assure accuracy of the computer program and results.

CHAPTER IV

PRESENTATION AND INTERPRETATION OF THE FINDINGS

It was the purpose of this investigation to determine the growth in critical thinking abilities and attitudes toward science of students as a result of a specific course in chemistry, the Chemical Education Material Study (CHEM Study) course. Chemistry students were compared to non-chemistry students using academic ability and academic achievement as covariance controls.

The data for the study were obtained by administering the Cornell Critical Thinking Test, Form X and the Reaction Inventory, Attitudes Toward Science and Scientific Careers to measure critical thinking abilities and attitudes toward science. The investigation was conducted during the 1966-67 academic year in the public high schools in Tacoma, Washington. The tests were administered in September, 1966 and in March, 1967 using a pre-test - post-test pattern as a research design. Data were further collected by analysis of school records. Data from the criterion tests and student records were noted and tabulated on data sheets and punched on IBM cards for statistical analysis.

The data from the school records were used to determine the subgroups used in the statistical design referred to in Chapter III. Group means, standard deviations and ranges of scores were determined for each group and compared. The data were also used for the testing of certain null hypotheses. In the tests of the null hypotheses group means, rather than individual scores were used, since it was the particular group and not the individual student being compared.

The null hypotheses to be tested were listed in Chapter I, and are considered in this investigation later in this chapter when the null hypotheses are individually examined. The criterion measure in each of the tests of the null hypotheses was the group mean on the Cornell Critical Thinking Test, Form X and the Reaction Inventory Attitudes Toward Science and Scientific Careers. The covariance controls used were:

1. The Numerical Ability score on the Differential Aptitude Test (DAT),
2. The composite score on the Verbal Reasoning, Numerical Ability score on the Differential Aptitude Test (DAT),
3. The total score on the School and College Ability Test (SCAT),
4. The Background in Natural Science score on the Iowa Test of Educational Development (ITED), and
5. The accumulative grade point average.

The groups were further placed into high and low subgroups based upon the aforementioned five controls. The subgroups consisted of the high one-third and low one-third of scores for each of the test scores and the grade point average.

Analysis of the Data

This section is concerned with the following factors which are hypothesized to be related to scores on the *Cornell Critical Thinking Test, Form X* and the *Reaction Inventory, Attitudes Toward Science and Scientific Careers:*

1. Academic achievement as measured by student scores on:
   a. The Numerical Ability Score on the *Differential Aptitude Test* (DAT).
   b. The composite score on the Verbal Reasoning, Numerical Ability score on the *Differential Aptitude Test* (DAT).
   c. The Background in Natural Science score on the *Iowa Test of Educational Development* (ITED).
2. Academic ability as measured by the total score on the *School and College Ability Test* (SCAT).

While the basic concern of this study was the growth in critical thinking abilities and attitudes toward science, it was also of primary importance to analyze the grade point averages, the *Differential Aptitude Test* scores, the *Iowa Test of Educational*

Development scores, and the School and College Ability Test test scores to determine the nature of the group under investigation.

Scores and Indications of Academic Achievement

Table 5 provides information regarding the nature of the sample based upon scores and criteria of academic achievement.

Table 5. Mean percentile scores, range, and standard deviations (σ) of numerical ability scores on the Differential Aptitude Test for chemistry and non-chemistry students.

Group	Mean (Percentile)	σ	Range (Percentile)
Chemistry Students	73.8	19.8	3-99
Non-chemistry Students	68.6	20.8	25-99

Table 5 shows that the chemistry students averaged somewhat higher in Numerical Ability than did the non-chemistry students. Analysis of the scores indicated that the differences between the means was much less than the standard deviation based on information from the Differential Aptitude Test handbook for administration (16, p. 38), hence, the groups were considered to be comparable for the investigation.

Table 6 shows that the chemistry students averaged slightly higher on the combined Verbal Reasoning and Numerical Ability score on the Differential Aptitude Test than did the non-chemistry students. Analysis of the scores indicated that the differences between the means was much less than the standard deviation based on information from the Differential Aptitude Test handbook for administration (16, p. 38), hence, the groups were considered to be comparable for the investigation.

Table 6. Mean percentile scores, range, and standard deviations (σ) of combined numerical ability and verbal reasoning scores on the Differential Aptitude Test for chemistry and non-chemistry students.

Group	Mean (Percentile)	σ	Range (Percentile)
Chemistry Students	75.8	18.7	25-99
Non-chemistry Students	69.5	20.0	25-99

The average of the chemistry students as noted in Table 7 was 71.5 percentile as compared to 69.5 percentile for the non-chemistry students based on the Background in Natural Science score on the Iowa Test of Educational Development. The difference was so slight that these groups were considered to be comparable for the investigation.

Table 7. Mean percentile scores, ranges, and standard deviations (σ) of background in Natural Science Score on the Iowa Test of Educational Development for chemistry and non-chemistry students.

Group	Mean (Percentile)	σ	Range (Percentile)
Chemistry Students	71.5	20.4	20-98
Non-chemistry Students	69.5	20.4	22-99

Table 8. Mean scores, range, and standard deviations (σ) of accumulative grade point averages for chemistry and non-chemistry students.

Group	Mean (Percentile)	σ	Range (Percentile)
Chemistry Students	2.81	.58	1.2-4.0
Non-chemistry Students	2.62	.56	1.1-4.0

The chemistry students averaged higher than did the non-chemistry students on grade point average as seen in Table 8. Analysis of the means and computation of the standard deviation (.57) indicated that the difference between the two groups was much less than a standard deviation, .19 as compared to .57, hence, the groups were considered to be comparable for the investigation.

Using the criteria available for academic achievement and analyzing the differences between the means of the groups, the two groups of the sample, chemistry and non-chemistry students appeared to be comparable. For analysis using covariance controls as a statistical control, the indicated scores seemed to be valid and comparable for the study.

Scores of Academic Ability

The following table (Table 9) provides information regarding the nature of the sample based upon scores of academic ability.

Table 9. Mean percentile scores, range, and standard deviations (σ) of total score on the School and College Ability Test for chemistry and non-chemistry students.

Group	Mean (Percentile)	σ	Range (Percentile)
Chemistry Students	78.2	17.2	10-99
Non-chemistry Students	68.1	22.6	20-99

The chemistry students averaged higher than did the non-chemistry students in the total score on the School and College Ability Test (Table 9). Analysis of the scores indicated that the differences between the means was much less than the standard deviation based on information from the School and College Ability Test handbook for administration (39, p. 21), hence, the groups were considered to be comparable for the investigation.

The preceding information provided evidence regarding the characteristics and composition of the population. Based upon test scores and use of controls in academic achievement and academic ability, the chemistry and non-chemistry students were judged to be comparable for the design of the investigation.

Critical Thinking Ability of Students

The critical thinking ability of the students was measured by scores on the Cornell Critical Thinking Test, Form X. The total means and standard deviations of the test results for the chemistry and non-chemistry students are shown in Table 10. Data from the first and second test are included. Both groups showed gains based upon the critical thinking test. The chemistry students indicated a gain of 6.10 points while the non-chemistry students showed a gain of 3.62 points. The groups also indicated less variance in the second test situation as compared to the first. This is noted in the analysis of the standard deviations. The chemistry students differed from the non-chemistry students in critical thinking abilities at the beginning of the investigation and at the conclusion.

Table 10. Mean scores and standard deviations (σ) of chemistry and non-chemistry students based upon the Cornell Critical Thinking Test, Form X (CCTT).

	Chemistry		Non-chemistry	
	Mean	σ	Mean	σ
CCTT - Test 1	42.70	10.9	37.92	12.2
CCTT - Test 2	48.80	9.2	41.54	10.2

Interesting developments about the data were investigated. Further examination of the critical thinking test indicated that the students who scored low initially did better on the second examination. Tables 11 and 12 show the range of test scores and the frequency of students in the first and second test of critical thinking ability.

As noted in Table 11, there were five chemistry students who scored 19 or less on the first test while none scored 19 or less on the second examination. Approximately 90 percent scored 25 or higher on the initial test while approximately 90 percent scored 35 or higher on the second examination.

As noted in Table 12, there were nine non-chemistry students who scored 19 or less on the first examination while none scored 19 or less on the second test. Approximately 90 percent scored 25 or higher on the initial test while approximately 90 percent scored 30 or higher on the second examination.

Table 13 lists the items that were missed by 35 percent or more of the total population in the first and second test. Items 1 through 24 are based upon the students' ability to use deduction; items 25 through 50 indicate the students' ability to recognize reliability in critical thinking; items 50 through 65 indicate the students' ability to use deduction; and, items 66 through 76 indicate the students' ability to recognize and find assumptions. All of the aforementioned

Table 11. Range and frequency of scores of chemistry students on the Cornell Critical Thinking Test, Form X.

Range of Scores	Test 1 Number of Students	Test 1 Percentage of total	Test 2 Number of Students	Test 2 Percentage of total
70-75	0	0	3	2. 1
65-69	2	1. 3	3	2. 1
60-64	2	1. 3	7	4. 7
55-59	19	12. 5	20	13. 4
50-54	20	13. 1	28	18. 8
45-49	19	12. 5	43	29. 1
40-44	44	28. 7	20	13. 4
35-39	19	12. 5	9	6. 3
30-34	8	5. 2	10	6. 7
25-29	12	7. 8	4	2. 7
20-24	3	1. 9	1	. 7
15-19	3	1. 9	0	0
10-14	0	0	0	0
5- 9	0	0	0	0
0- 4	2	1. 3	0	0
Totals	153	100	148	100

Table 12. Range and frequency of scores of non-chemistry students on the Cornell Critical Thinking Test, Form X.

Range of Scores	Test 1 Number of Students	Test 1 Percentage of total	Test 2 Number of Students	Test 2 Percentage of total
70-75	0	0	0	0
65-69	0	0	0	0
60-64	2	1.3	4	2.8
55-59	11	7.4	14	9.7
50-54	15	10.1	18	12.5
45-49	17	11.4	24	16.6
40-44	36	24.2	22	15.3
35-39	22	14.8	25	17.3
30-34	17	11.4	22	15.3
25-29	13	8.8	10	7.0
20-24	7	4.7	5	3.5
15-19	2	1.3	0	0
10-14	2	1.3	0	0
5- 9	0	0	0	0
0- 4	5	3.3	0	0
Totals	149	100	144	100

were included in the definition of critical thinking as used in the preparation of the Cornell Critical Thinking Test, Form X.

Table 13. Cornell Critical Thinking Test items missed by 35 percent or more of chemistry and non-chemistry students.

Item Number	Percent missing item Test 1	Percent missing item Test 2	Aspect of critical thinking
9	49	39	Induction
10	69	70	Induction
14	69	57	Induction
15	66	48	Induction
16	84	76	Induction
20	47	51	Induction
27	68	84	Reliability
29	39	28	Reliability
30	38	21	Reliability
36	71	69	Reliability
38	69	45	Reliability
71	79	80	Assumption-Finding
75	63	65	Assumption-Finding

Based on percentages of the total, the students appeared to gain in inductive ability and somewhat in reliability as aspects of critical thinking. However, the students did not show gains in their ability to find assumptions as measured by the Cornell Critical Thinking Test, Form X.

Table 14. Differences in mean scores and standard deviations (σ) of chemistry and non-chemistry students compared to scientists based upon the Reaction Inventory, Attitudes Toward Science and Scientific Careers.

	Chemistry		Non-chemistry	
	mean	σ	mean	σ
Test 1	45.57	8.42	48.76	9.37
Test 2	40.16	7.28	50.26	9.61

Both groups were considered to have favorable attitudes toward science at the beginning of the investigation. This assumption is made by use of the scoring method employed by Allen (1). Scores such as 50.26 or better were considered to be favorable attitudes toward science. The chemistry students showed a positive growth in attitudes and the non-chemistry students did not show a positive growth in attitudes toward science during the time interval. The chemistry students showed a mean gain of 5.41 while the non-chemistry students showed no gain in attitudes toward science (-1.50).

An analysis of the attitude scale showed some items that were frequently missed by many students. The responses of the students were quite different from the scientists with respect to certain items as indicated on Table 15. Most of the discrepancy was in the area of scientific careers and indicated a lack of understanding on the part of the students as to the nature of the work of the scientist.

Students were also in agreement with scientists on many items on the Reaction Inventory. These items are listed and mean scores given in Table 16. Analysis of the nature of the items indicated that the students are in close agreement with respect to the interaction between science and society.

Tests of Null Hypotheses

In the tests of null hypotheses, the statistical model employed was the pre-test - post-test design as recommended by Gage (50, p. 178). Group means were used as the unit of analysis, since it was group differences rather than individual differences that were being tested. Instruments used in the investigation were the Cornell Critical Thinking Test, Form X and the Reaction Inventory, Attitudes Toward Science and Scientific Careers.

Covariance controls used in the study included the following:

1. The Numerical Ability score on the Differential Aptitude Test,
2. The combined Numerical Ability and Verbal Reasoning score on the Differential Aptitude Test,

Table 15. Items showing greatest difference in student response from scientists' responses on the Reaction Inventory.

Scientists' Mean*	Item	Students' Mean*
.18	17. Science requires creative activity	1.20
3.82	25. It is undemocratic to favor exceptional scientific talent	2.78
3.82	31. Science is primarily a method for inventing new devices	2.64
3.77	41. Scientific work is boring	2.87
3.71	44. I don't have the intelligence for a successful scientific career	2.72
1.29	49. The scientist can expect to accumulate little wealth as compensation for his work	2.36
2.24	54. A great research scientist is little concerned with the practical considerations of his work	3.06
.41	70. Scientific concepts and discoveries often bring about new sociological problems	1.31
3.77	80. Many specific findings in science contradict the laws of God	2.33
.24	85. The working scientist believes that nature is rather orderly than disorderly	1.08

*Using scale that 0 represents complete agreement and 4 respresents complete disagreement.

Table 16. Items showing most favorableness between students and scientists based on the Reaction Inventory

Scientists' Mean*	Item	Students' Mean*
3.29	3. Scientists are seldom concerned with their working conditions	3.07
1.00	4. The development of new ideas is the scientist's greatest source of satisfaction	.76
.77	9. Industries use research as a means to improve their economic position	.81
2.06	21. The complexity of science hides its cultural value	2.08
3.29	23. Scientists possess too much power in our society	3.12
1.59	40. The use of scientific achievement is often hampered by selfish individuals	1.61
3.00	52. Scientists are "eggheads"	3.12
2.35	63. The engineer serves a more practical purpose in our society than does the research scientist	2.51
3.18	71. Scientists are against formal religion	2.98
1.47	86. The modern world is dominated by science	1.48
.53	90. Curiousity motivates the scientist to make discoveries	.64
.71	91. The chief reward in scientific work is the thrill of discovery	.72

*Using scale that 0 represents complete agreement and 4 represents complete disagreement.

3. The Background in Natural Science score on the Iowa Test of Educational Development,

4. The total score on the School and College Ability Test, and

5. The accumulative grade point average of the students.

High and low subgroups were determined by using the highest and lowest one-third of scores in each of the above mentioned criteria.

In this chapter, tests of null hypotheses which were stated in Chapter I are presented and discussed. T-tests were computed to determine whether differences in group means on the tests were significant.

There is No Difference In Growth In Critical Thinking Abilities Between Chemistry Students and the Critical Thinking Abilities of Non-chemistry Students

The results of the critical thinking test scores for the chemistry and non-chemistry students are found in Table 17. The mean scores of the chemistry students were compared to the mean scores of the non-chemistry students. Both groups showed gains in critical thinking abilities, 6.10 for chemistry students as compared to 3.62 for non-chemistry. The chemistry students showed the greatest gains from the first test to the second. However, the t-value of .23 was too small to be a significant difference, so the null hypothesis was accepted indicating no real difference between the two groups in critical thinking abilities as measured by the Cornell Critical Thinking Test, Form X.

Table 17. Relationship of critical thinking ability of chemistry and non-chemistry students.

Group	n	Mean difference	ndf*	t value	Level of significance
Chemistry	153	6.10	152		
				.23	-
Non-chemistry	149	3.62	148		

*Number of degrees of freedom.

There Is No Difference in Growth in Critical Thinking Abilities Between Chemistry Students in the High and Low Subgroups Based upon the Total Score on the SCAT Test and the Non-chemistry Students in the High and Low Subgroups Based upon the Total Score on the SCAT Test

The results of the critical thinking tests scores for these groups are found in Table 18. The means of the chemistry students were compared to the mean scores of the non-chemistry students. All groups made gains in critical thinking ability with chemistry students showing the greatest gains. The low subgroup made greater gains than did the high subgroup for chemistry and non-chemistry students. While gains were shown for both groupings, the t-values were small and did not indicate any significant differences in critical thinking abilities for these groups based upon the critical thinking test. Hence, the null hypotheses were accepted.

Table 18. Relationship of critical thinking ability of chemistry and non-chemistry students based upon total score on the SCAT test.

	n.	Mean difference	ndf	t value	Level of significance
High Group					
Chemistry	46	8.49	45	.71	-
Non-chemistry	43	2.03	42		
Low Group					
Chemistry	47	9.80	46	.38	-
Non-chemistry	43	4.75	43		

There Is No Difference in Growth in Critical Thinking Abilities Between Chemistry Students in the High and Low Subgroups on the Accumulative Grade Point Average and the Non-chemistry Students in the High and Low Subgroups Based on the Accumulative Grade Point Average

The results of the critical thinking test scores for these groups are found in Table 19. The mean scores of the chemistry students were compared to the mean scores of the non-chemistry students. All groups showed gains in critical thinking ability with chemistry students making the greatest gains. The low subgroup of chemistry students made the greatest gain in critical thinking ability. Gains were indicated for the high and low subgroups but the low value for t indicates that there are no significant differences between the mean scores on critical thinking ability based on the *Cornell Critical Thinking Test, Form X*.

Table 19. Relationship of critical thinking ability of chemistry and non-chemistry students based upon the accumulative grade point average.

	n	Mean difference	ndf	t value	Level of significance
High Group					
Chemistry	50	6.72	49	.41	-
Non-chemistry	47	2.69	46		
Low Group					
Chemistry	48	8.32	47	.33	-
Non-chemistry	46	4.43	45		

There Is No Difference in Growth in Critical Thinking Abilities Between Chemistry Students in the High and Low Subgroups Based upon the Numerical Ability Score on the DAT and the Non-chemistry Students in the High and Low Subgroups Based upon the Numerical Ability Score on the DAT Test

The results of the critical thinking test scores for these groups are found in Table 20. The mean scores of the chemistry students were compared to the mean scores of the non-chemistry students. All groups showed gains in critical thinking ability with chemistry students making the greatest gains. The low subgroup of chemistry students showed the greatest gain in critical thinking ability. While gains were indicated for all groups, the t-value was too small to indicate any significant difference between the groups. Hence, it was accepted that there was no difference in critical thinking ability between the groups based upon scores on the criterion instrument.

Table 20. Relationship of critical thinking ability of chemistry and non-chemistry students based upon the numerical ability score on the DAT test.

	n	Mean difference	ndf	t value	Level of significance
High Group					
Chemistry	42	5.49	41	.30	-
Non-chemistry	48	2.74	47		
Low Group					
Chemistry	48	5.91	47	.05	-
Non-chemistry	44	5.23	43		

There Is No Difference in Growth in Critical Thinking Abilities Between Chemistry Students in the High and Low Subgroups Based upon the Combined Numerical Ability and Verbal Reasoning Score on the DAT Test and the Non-chemistry Students in the High and Low Subgroups Based upon the Combined Numerical Ability and Verbal Reasoning Score on the DAT Test

The results of the critical thinking test scores for these groups are found in Table 21. The mean scores of the chemistry students were compared to the mean scores of the non-chemistry students. The four groups showed gains in critical thinking abilities with chemistry students showing the greatest gains. The chemistry students in the low subgroup showed the greatest gain in critical thinking ability. While gains were indicated, there was no significant difference between the groups based upon scores on the critical thinking test as seen in the calculated t-value.

Table 21. Relationship of critical thinking ability of chemistry and non-chemistry students based upon the combined Numerical Ability and Verbal Reasoning score on the DAT test.

	n	Mean difference	ndf	t value	Level of significance
High Group					
Chemistry	52	5.27	51	.39	-
Non-chemistry	47	1.70	46		
Low Group					
Chemistry	52	7.06	51	.11	-
Non-chemistry	49	5.70	48		

There Is No Difference in Growth in Critical Thinking Abilities Between Chemistry Students in the High and Low Subgroups Based upon the Background in Natural Science Score in the ITED Test and the Non-chemistry Students in the High and Low Subgroups Based upon the Background in Natural Science Score on the ITED Test

The results of the critical thinking test scores for these groups are found in Table 22. The mean scores of the chemistry students were compared to the mean scores of the non-chemistry students. All groups showed gains in critical thinking ability with chemistry students making the greatest gains. The low subgroup of chemistry students made the greatest gains in critical thinking abilities. Chemistry students made greater gains, but not enough to be significant (.33 and .14) based on t-values, hence, it was accepted that there was no signficant difference between the growth in critical thinking abilities of these groups based upon scores on the Cornell Critical Thinking Test, Form X.

Table 22. Relationship of critical thinking ability of chemistry and non-chemistry students based upon the Background in Natural Science Score on the ITED test.

	n	Mean difference	ndf	t value	Level of significance
High Group					
Chemistry	48	6.31	47	.33	-
Non-chemistry	46	2.68	45		
Low Group					
Chemistry	44	8.09	43	.14	-
Non-chemistry	43	6.37	42		

There Is No Difference in Growth of Attitudes Toward Science Between Chemistry Students and the Attitudes Toward Science of Non-chemistry Students

The results of the attitudes toward science tests for the chemistry and non-chemistry students are found in Table 23. The mean scores of the chemistry students were compared to the mean scores of the non-chemistry students. The chemistry students showed a positive gain in attitudes toward science whereas the non-chemistry students did not indicate any gain. The t-value of 1.30 is significant only at the .10 level and this is not usually considered to be a significant difference between the growth in attitudes toward science between the chemistry and non-chemistry students based upon scores of the Reaction Inventory, Attitudes Toward Science and Scientific Careers.

Table 23. Relationship of attitudes toward science of chemistry and non-chemistry students.

Group	n	Mean difference	ndf	t value	Level of significance
Chemistry	153	5.41	152	1.30	t < .10
Non-chemistry	149	-1.50	148		

There Is No Difference in Growth of Attitudes Toward Science Between Chemistry Students in the High and Low Subgroups Based upon the Total Score on the SCAT Test and the Non-chemistry Students in the High and Low Subgroups Based upon the Total Score on the SCAT Test

The results of the attitudes toward science tests for these groups are found in Table 24. The mean scores of the chemistry students were compared to the mean scores of the non-chemistry students. In the high group the chemistry and non-chemistry students did not show a growth in attitudes toward science. In the low group, the chemistry students indicated a greater gain in attitudes toward science than did the non-chemistry students. The low t-values for both groups (.37 and .49) did not provide evidence for any significant differences in growth in attitudes toward science between these groups based upon scores on the Reaction Inventory, hence, the null hypotheses were accepted.

Table 24. Relationship of attitudes toward science of chemistry students and non-chemistry students based upon the total score on the SCAT test.

	n	Mean difference	ndf	t value	Level of significance
High Group					
Chemistry	46	- .79	45	.37	-
Non-chemistry	43	-1.52	42		
Low Group					
Chemistry	47	3.98	46	.49	-
Non-chemistry	43	.69	43		

There Is No Difference in Growth in Attitudes Toward Science Between Chemistry Students in the High and Low Subgroups Based upon the Accumulative Grade Point Average and the Non-chemistry Students in the High and Low Subgroups Based upon the Accumulative Grade Point Average

The results of the attitudes toward science test for these groups are found in Table 25. The mean scores for the chemistry students were compared to the mean scores of the non-chemistry students. The chemistry students in both subgroups showed gains in attitudes toward science while the non-chemistry students did not indicate any gains. The computed t-values for both groups were not large enough to provide evidence for a significant difference. Hence, it was determined that no significant difference was found between the growth in attitudes toward science between the chemistry and non-chemistry students based upon scores on the criterion instrument for attitudes toward science.

Table 25. Relationship of attitudes toward science of chemistry and non-chemistry students based upon the accumulative grade point average.

	n	Mean difference	ndf	t value	Level of significance
High Group					
Chemistry	50	3.14	49	.99	-
Non-chemistry	47	-1.34	46		
Low Group					
Chemistry	48	2.84	47	.96	-
Non-chemistry	46	-2.18	45		

There Is No Difference in Growth in Attitudes Toward Science Between Chemistry Students in the High and Low Subgroups Based upon the Numerical Ability Score on the DAT Test and the Non-chemistry Students in the High and Low Subgroups Based upon the Numerical Ability Score on the DAT Test

The results of the attitudes toward science test for these groups are found in Table 26. The mean scores of the chemistry students were compared to the mean scores of the non-chemistry students. In the high group the chemistry students showed gains in attitudes toward science while the other did not indicate any gain.

In analysis of significant differences, the chemistry students in the high subgroup showed a significant difference at the .05 level (1.76) over the non-chemistry students. Hence, it was accepted that there was a significant difference between the growth in attitudes between the chemistry and non-chemistry students based on controlling the Numerical Ability score on the DAT Test.

Table 26. Relationship of attitudes toward science of chemistry and non-chemistry students based upon the Numerical Ability score on the DAT Test.

	n	Mean difference	ndf	t value	Level of significance
High Group					
Chemistry	42	10.21	41	1.76	t < .05
Non-chemistry	48	-1.92	47		
Low Group					
Chemistry	48	0.02	47	.17	-
Non-chemistry	44	-1.09	43		

There Is No Difference in Growth in Attitudes Toward Science Between Chemistry Students in the High and Low Subgroups Based upon the Combined Numerical Ability and Verbal Reasoning Score on the DAT Test and the Non-chemistry Students in the High and Low Subgroups Based upon the Combined Numerical Ability and Verbal Reasoning Score on the DAT Test

The results of the attitudes toward science tests for these groups are found in Table 27. The mean scores of the chemistry students were compared to the mean scores of the non-chemistry students. The largest gains in attitudes toward science were found in the non-chemistry student scores in the high subgroup. The non-chemistry students showed greater gains in growth in attitudes toward science than did the chemistry students in both subgroups. On the basis of the calculated t-values (-.23 and -.92) it was determined that no significant differences in growth in attitudes existed between these groups based upon scores on the criterion attitude test.

Table 27. Relationship of attitudes toward science of chemistry and non-chemistry students based upon the combined Numerical Ability and Verbal Reasoning score on the DAT Test.

	n	Mean difference	ndf	t value	Level of significance
High Group					
Chemistry	52	3.55	51	-.23	-
Non-chemistry	47	5.05	46		
Low Group					
Chemistry	52	-1.11	51	-.92	-
Non-chemistry	49	4.82	48		

<u>There Is No Difference in Growth in Attitudes Toward Science Between Chemistry Students in the High and Low Subgroups Based upon the Background in Natural Science Score on the ITED Test and the Non-chemistry Students in the High and Low Subgroups Based upon the Background in Natural Science Score on the ITED Test</u>

The results of the attitudes toward science tests for these groups are found in Table 28. The mean scores of the chemistry students were compared to the mean scores of the non-chemistry students. According to Table 28, the chemistry students indicated greater gains in growth in attitudes toward science than did the non-chemistry students in both groups. In the high subgroup, the calculated t-value (1.48) indicated a significant difference at the .10 level between the chemistry and non-chemistry students. This is not usually considered to be a significant difference. Hence, on the basis of the calculated t-value for both subgroups it was concluded that there was no significant difference in growth in attitudes toward science between chemistry and non-chemistry students in the groups based upon scores on the <u>Reaction Inventory</u>.

Table 28. Relationship of attitudes toward science of chemistry and non-chemistry students based upon the Background in Natural Science score on the ITED Test.

	n	Mean difference	ndf	t value	Level of significance
High Group					
Chemistry	48	8.87	47	1.48	t < .10
Non-chemistry	46	0.19	45		
Low Group					
Chemistry	44	4.30	43	.77	-
Non-chemistry	43	-1.80	42		

Summary and Conclusions

This chapter has indicated the development of the test results through analysis. The purpose for doing this was explained as well as the procedure. Analysis of means was used to statistically test the null hypotheses based on group means on the Cornell Critical Thinking Test, Form X and the Reaction Inventory, Attitudes Toward Science and Scientific Careers. T-tests were used to determine whether differences in group means on the tests were significant.

Data from school records and the analysis of the means and standard deviations indicated that the chemistry and non-chemistry students were quite comparable in academic achievement and academic ability.

Based on the Cornell Critical Thinking Test, Form X chemistry and non-chemistry students showed gains in critical thinking ability from the September to March testing dates. Greatest gains were shown by the chemistry students in the investigation. However, no significant differences were noted in any of the subgroups of chemistry and non-chemistry students. In each case, the null hypotheses related to critical thinking as presented in Chapter I were accepted. It was interesting to note, however, that the low subgroups for each of the covariance controls indicated greater gains in critical thinking ability than did the high subgroups.

Student attitudes toward science were measured by the Reaction Inventory, Attitudes Toward Science and Scientific Careers. Gains in attitudes were noted for most groups of chemistry students and no gains for most groups of non-chemistry students. Based on scores and related studies, it was determined that the students had rather favorable attitudes toward science at the beginning of the investigation. The following results were most notable with respect to attitudes toward science:

1. Controlling statistically the Numerical Ability score on the Differential Aptitude Test, the high subgroup of chemistry students scored significantly higher in growth in attitudes toward science than did the high subgroup of non-chemistry students. The calculated t-value of 1.76

was significant at the .05 level of significance.

2. The total group of chemistry students indicated a .10 level of significance when compared to the non-chemistry students based on mean differences on the Reaction Inventory.

3. Controlling statistically the Background in Natural Science score on the Iowa Test of Educational Development the high subgroup of chemistry students indicated a .10 level of significance when compared to the non-chemistry students based on mean difference scores of the Reaction Inventory.

While the .10 level of significance is usually not considered to determine significant differences, the investigator felt that it was important to note this result in the investigation. It was further noted that the attitudes toward science and scientific careers of chemistry students became more favorable during the school year.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

This study was designed to compare the growth in attitudes toward science and the critical thinking abilities of high school juniors in chemistry to juniors not enrolled in chemistry. One hundred and fifty-three chemistry students and 149 non-chemistry students were involved in the investigation. All were students in the Tacoma Public Schools and were randomly selected.

Students were pre-tested in the fall to control scholastic ability and relevant knowledge. Post-testing was conducted in the spring to determine the extent of growth in attitudes toward science and critical thinking abilities.

The criterion tests used were the *Reaction Inventory, Attitudes Toward Science* and *Scientific Careers and the Cornell Critical Thinking Test, Form X.*

To statistically control the academic achievement and academic ability of the students, the following covariance controls were used:

1. The Numerical Ability score on the *Differential Aptitude Test,*

2. The combined Verbal Reasoning and Numerical Ability score on the Differential Aptitude Test,

3. The Background in Natural Science score on the Iowa Test of Educational Development,

4. The total score on the School and College Ability Test, and

5. The accumulative grade point average.

For purposes of evaluation, the participants were grouped into high and low subgroups based upon the aforementioned criteria. Each subgroup consisted of approximately one-third of the chemistry and non-chemistry students.

Analysis of mean scores and standard deviations of each of the covariance controls indicated similarities between the chemistry and non-chemistry students in academic achievement and ability. Based on analysis of the student records, the various groups were considered to be comparable for the investigation.

The t-test was used to statistically determine any significant differences between the groups. Group means rather than individual scores were used as the unit of analysis since it was the participating groups and not the individuals under consideration. Analysis was based on the .01 and .05 levels of significance.

The Cornell Critical Thinking Test, Form X sampled the students' critical thinking abilities. Analysis indicated that all groups obtained positive gains in critical thinking ability. Chemistry students showed greater gains in every subgroup over non-chemistry students. Greater gains were noted in the low subgroups of chemistry and non-chemistry students compared to the high subgroups. No significant differences were noted between the chemistry and non-chemistry students.

Based on scores on the Reaction Inventory, Attitudes Toward Science and Scientific Careers the participants in the study had generally favorable attitudes toward science at the beginning of the investigation. Chemistry students showed gains in growth in attitudes toward science while the non-chemistry students showed no gains. Attitudes toward science of chemistry students became more favorable during the school year.

Statistically comparing the growth in attitudes toward science of chemistry students and non-chemistry students resulted in a calculated t-value of 1. 30. This is significant at the . 10 level in favor of the chemistry students. However, the . 10 level is not usually considered to be an indication of significant difference.

Statistically controlling the Background in Natural Science score on the Iowa Test of Educational Development the high subgroup of chemistry students indicated a calculated t-value of 1. 48 when compared to the non-chemistry students. This is significant at the . 10 level in favor of the chemistry students. However, the . 10 level is not usually considered to be an indication of significant difference.

Statistically controlling the Numerical Ability score on the *Differential Aptitude Test*, the high subgroup of chemistry students indicated a significant difference in growth in attitudes toward science over the non-chemistry students. The calculated t-value was 1.76 which is significant at the .05 level. This level is considered to be an indication of significant difference between the groups.

Conclusions

Twenty-two null hypotheses were tested in this study (stated on pages 4 through 10). The eleven null hypotheses relating to critical thinking abilities were tested and accepted. (Statistical treatment presented in Chapter IV). Ten of the eleven null hypotheses relating to attitudes toward science were tested and accepted. (Statistical treatment presented in Chapter IV). The following null hypothesis was rejected:

> There is no difference in growth in attitudes toward science between chemistry students in high subgroup based upon the Numerical Ability score on the *Differential Aptitude Test* and the non-chemistry students in the high subgroup based upon the Numerical Ability score on the *Differential Aptitude Test*.

The calculated t-value of 1.76 indicated a significant difference at the .05 level between the chemistry and non-chemistry students.

Other conclusions were attained as a result of this study. It may be concluded that:

1. There is no significant difference in the growth in critical thinking abilities as measured by the Cornell Critical Thinking Test, Form X between chemistry and non-chemistry students.
2. There is no significant difference in the growth in critical thinking abilities as measured by the Cornell Critical Thinking Test, Form X between chemistry and non-chemistry students using the covariance controls indicated in the investigation.
3. Chemistry students made greater gains in growth in critical thinking abilities than non-chemistry students as measured by the Cornell Critical Thinking Test, Form X.
4. Chemistry and non-chemistry students in the low sub-groups of the covariance controls indicated greater gains in growth in critical thinking abilities than did the high subgroups as measured by the Cornell Critical Thinking Test, Form X.
5. There is no significant difference in growth in attitudes

toward science between chemistry and non-chemistry students as measured by the _Reaction Inventory, Attitudes Toward Science and Scientific Careers._

6. When statistically controlling the Numerical Ability score on the _Differential Aptitude Test_, the high subgroup of chemistry students scored significantly higher than did the high subgroup of non-chemistry students on the _Reaction Inventory, Attitudes Toward Science and Scientific Careers._

7. Chemistry students made positive gains in growth in attitudes toward science as measured by the _Reaction Inventory, Attitudes Toward Science and Scientific Careers._

8. Non-chemistry students did not make positive gains in growth in attitudes toward science as measured by the _Reaction Inventory, Attitudes Toward Science and Scientific Careers._

Recommendations

On the basis of this investigation, the following recommendations are presented:

1. A comparable study of critical thinking abilities and attitudes toward science be conducted in other school districts.

2. A comparable study of critical thinking abilities and attitudes toward science be done on a larger population.
3. A study be done to determine the relationship of critical thinking ability to the selection of chemistry as a subject.
4. A study be done to analyze the CHEM Study course to determine specifically which aspects of the course develop critical thinking abilities.
5. An investigation be done relating the results of the tests with grades earned and teacher recommendations following completion of one semester of chemistry.
6. Other studies be done to evaluate attainment of other objectives related to science education.
7. A study be done of the guidance practices in various school districts regarding the placement of students in science courses.
8. A study of related background in science and mathematics and the influence of these criteria on attitudes toward science be done.
9. A study be done of the effect of the "new" mathematics on the critical thinking ability with respect to the induction, deduction aspect of critical thinking.

The foregoing generalizations do not include all of the recommendations that this study might suggest. However, each suggestion does seem to be of basic importance to science education.

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CORNELL CRITICAL THINKING TEST, FORM X

by Robert H. Ennis and Jason Millman

Exploring In Nicoma

The year is 1990. It is the middle of June. Imagine yourself to be in the second group from the United States to land on the newly-discovered planet, Nicoma. Nothing has been heard from the first group, which landed on Nicoma two years earlier. Your group is going to investigate and bring a report back to earth.

In what follows you will be told about the investigation. Then you will be asked questions that call for clear thinking. Answer these questions as if the facts given were true.

Do not guess wildly at these questions. If you have no idea what the answer is, omit the question. If you have a good idea, even though you are not positive, answer the question.

This test takes fifty minutes. You will be able to finish, if you do not spend too much time on any one question. Work carefully, because in the first two sections you must not go back to an item once you have passed it.

Now take your answer sheet and print your name and the other information requested.

Wait for your teacher to tell you to begin.

Part I, Section A - <u>What Happened to the First Group?</u>

The first job of your group is to find out what happened to the first group of 15 explorers. Your group has landed on Nicoma and has just discovered the metal huts put up by the first group. The huts appear to be in good condition from the outside. It is a warm day and the sun is shining. The trees, rocks, grass, and birds make this part of Nicoma appear about like parts of central United States.

You and the health officer are the first to arrive at the group of huts. You call out, but get no answer.

The health officer suggests, "Maybe they're all dead." You investigate.

Below are listed a number of facts which you learn. For each fact you must decide if it would be evidence for, or evidence against, <u>the health officer's idea that they are all dead</u>. However, the fact might not be either.

For each fact mark one of the following on your answer sheet:

A. This fact is <u>evidence in support</u> of the health officer's idea that they are all dead.

B. This fact is <u>evidence against</u> the health officer's idea that they are all dead.

C. <u>Neither</u>. Discovery of this fact makes no difference.

Here is a sample:

1. You go into the first hut. Everything is covered by a thick layer of dust.

This fact is evidence in support of the health officer's idea. It certainly is not enough to prove his idea, but is evidence for it. Using the special pencil, blacken the space under <u>A</u> for number 1 on your answer sheet--like this:

```
A     B     C
• •   • •   • •
• •   • •   • •
• •   • •   • •
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Here is another example:

2. Other members of your group discover the first group's rocket ship nearby.

What do you say about that fact? Mark your answer by number <u>2</u> on your answer sheet. Do it now.

You should have marked <u>C</u>. This fact about the rocket ship does not help us decide whether the members of the first group are dead. If you did not mark <u>C</u>, erase your mark thoroughly and mark <u>C</u>.

<u>Go on to the next page</u>.

Here is a list of facts. For each one mark A, B, or C. If you have no idea which to mark, leave that one blank and go on to the next one. Consider the bearing of each fact at the time that it becomes known. Do so in the order in which they are numbered. Work slowly and carefully, and do not return to an item once you have left it. Reminder--mark as follows:

A. This fact is evidence in support of the health officer's idea that they are all dead.

B. This fact is evidence against the health officer's idea that they are all dead.

C. Neither.

3. There are ten huts. You go into the second hut and again find that everything is covered by a thick layer of dust.

4. You go into the third hut. There is no dust on the cookstove.

5. You find a can opener by the cookstove in the third hut.

6. In the third hut you find a daily record of the activities of a member of the first group. It is written by a man named John Stilltron. The date of the last entry, July 2, 1988, is one month after the arrival of the first group.

7. You find that the two beds in the third hut are covered with a thick layer of dust.

8. You read the first entry in Stilltron's record: "June 2, 1988. We arrived today after a tiring trip. We put up the huts near our landing place."

9. You read the second entry in Stilltron's record: "June 3, 1988. There is a plentiful supply of food. Ducks, squirrels, and deer are here and are easily caught."

10. You read the third entry in Stilltron's record: "June 4, 1988. The water in the nearby stream has been tested by our health official. He has declared it safe to drink. We are not drinking it yet. We're going to try it with some guinea pigs we brought from the earth."

11. You read the last entry in the book: "July 2, 1988. I am getting weaker and can't hold out much longer."

12. In different handwriting below the last entry, you read, "John Stilltron died the same day."

13. The health officer has now looked in each of the ten huts. He reports that there is a thick layer of dust in each of them.

14. You proceed to examine the beds in each of the first three huts. You find that in each case the blankets and sheets are stripped from the beds and folded neatly in the closets.

Go on to the next page.

Reminder--mark as follows:

A. This fact is evidence in support of the health officer's idea that they are all dead.

B. This fact is evidence against the health officer's idea that they are all dead.

C. Neither.

15. The health officer reports that the beds in all the other huts are in the same condition. The blankets and sheets are neatly folded in the closets.

16. You notice a mound of earth behind Stilltron's hut. You examine it and find a stone with this inscription: "John Stilltron. July 2, 1988. He died as he lived--with honor."

17. The truck possessed by the first group is missing.

18. You investigate in the tenth hut and find a note dated March 15, 1990:

> If anyone should come looking for us, we have all gone exploring in the truck. We plan to head in the direction of the sunrise. (Signed) Captain Sardus, Leader of the Nicoma Explorers.

19. You see a note added at the bottom:

> P. S. We plan to be back within a week.

20. Eight members of your group get in one of your groups trucks and head in the direction of the sunrise. You follow a rough broad valley for 20 miles and find the first group's truck apparently abandoned by a stream.

21. You discover a note in the driver's seat:

> Engine breakdown. We plan to hike downstream. Perhaps there's a large body of water in that direction. (Signed) Captain Sardus.

22. One of the eight, who is a mechanic, examines the abandoned truck's engine. He declares that it is in bad condition.

23. You observe that the truck's front tires are flat.

24. You start to drive downstream, since the land is level and clear. After 10 miles of driving, you see smoke rising in the distance. So far as you know, there are no volcanoes on Nicoma.

25. You soon come to a cliff too sharp for the truck. So all eight of you get out and walk toward the smoke.

Go on to the next page.

Part I, Section B - Examining the Village on Nicoma

It grows dark, so you camp overnight. You set out again in the morning. After walking for an hour, your party comes upon an empty village of stone huts. The sun is shining brightly. Various pieces of information are presented to you, since you are the leader of the party.

In what follows you will be given pieces of information, two at a time. You must decide which, if either, is more reliable. For each pair mark as follows:

A. The first is more reliable.
B. The second is more reliable.
C. They are equally reliable or unreliable.

Here is an example: (The information is underlined in each case)

26. A. The auto mechanic investigates the stream by the village and reports, "The water is not safe to drink."

B. The health officer says, "We can't tell yet if the water is safe to drink."

C. Equally reliable or unreliable.

What answer did you mark? You should have marked B. The underlined material in B is more dependable than the underlined material in A.

Here are some more pairs. Consider each pair in order at the time the information is offered.

27. A. The mechanic says, "The water looks clear."

B. The health officer, after making tests, says, "The water is good to drink."

C. Equally reliable or unreliable.

28. A. The health officer says, "This water is safe to drink."

B. Several other men are soldiers. One of them says, "This water supply is not safe."

C. Equally reliable or unreliable.

29. A. One soldier looks at some smoke rising. The smoke appears to him to be just behind the largest stone hut, which is on a hill about 100 yards away. He concludes, "The source of that smoke must be about 100 yards away."

B. Another soldier, who has just been behind the largest hut, says, "Oh no, the source is much farther than that."

C. Equally reliable or unreliable.

Go on to the next page.

Reminder--mark as follows:

A. The first is more reliable.
B. The second is more reliable.
C. They are equally reliable or unreliable.

30. A. The mechanic has made a quick round of the stone huts and heard a noise in the nearest hut. "There must be someone in that hut," he reports.

B. The health officer, who was in the nearest hut for several minutes reports, "Nobody is in that hut."

C. Equally reliable or unreliable.

31. A. The health officer concludes on the basis of his examination of the nearest hut, "The first group of explorers probably built that hut."

B. The anthropologist (a specialist in the study of races, tribes, and civilizations) also examined the nearest stone hut. He states, "The first group probably did not build the hut."

C. Equally reliable or unreliable.

You take your group to the top of the hill behind the largest stone hut to investigate the smoke. In the distance you see a group of about 40 figures gathered around a smoky fire.

Your captain has offered a bonus of $100 to the person who first sees any one of the missing explorers. You would each like the honor of being the first to see them--if they are there. But at the same time you are careful, because these figures around the fire may be dangerous. There are several pairs of field glasses in the group. The sun is still shining brightly. With field glasses one can count the logs on the fire.

32. A. The mechanic, looking through his field glasses, says, "They are tan-skinned creatures with furry spots."

B. The anthropologist, looking through his field glasses, says, "They don't have furry spots. They are wearing skins of animals."

C. Equally reliable or unreliable.

33. A. The mechanic says, "I think there are 40 of them."

B. The anthropologist says, "No, I think there are only 37."

C. Equally reliable or unreliable.

34. A. The anthropologist exclaims, "That's Captain Sardus there on the left by himself!"

B. The mechanic reports, "That's Sergeant Edema who just stood up on the right."

C. Equally reliable or unreliable.

Go on to the next page.

Reminder--mark as follows:

A. The first is more reliable.
B. The second is more reliable.
C. They are equally reliable or unreliable.

35. A. You borrow the anthropologist's glasses and say, "Yes, that's Sergeant Edema!"

B. At the same time, the health officer, who has borrowed the mechanic's glasses, says, "Yes, that's Sergeant Edema!"

C. Equally reliable or unreliable.

Now the question is whether the man on the left is Captain Sardus. If so, then the reward goes to the anthropologist. If not, it goes to the mechanic.

36. A. The health officer then looks through his field glasses at the one on the left. "That's not Captain Sardus," he says.

B. The anthropologist, who has his glasses again, replies, "Yes, it is."

C. Equally reliable or unreliable.

Then the man at the left rejoins the group of figures and another person takes his place.

37. A. The health officer says, "That new one is not one of the fourteen explorers."

B. The anthropologist agrees, "You're right, he's not."

C. Equally reliable or unreliable.

38. A. The anthropologist continues, "And look! There's Captain Sardus facing our way with his hand over his eyes. That's the same person as the one I called Captain Sardus before. I've been following him."

B. The health officer says, "Yes, that's Captain Sardus facing us now. But he's not the one who was over there on the left. That one is sitting down with his back to us. I've been following him, too."

C. Equally reliable or unreliable.

You ask them to see if they can agree on the number of beings in the group so that you can give an accurate report.

39. A. The health officer has had practice counting large numbers of objects on microscope slides. He announces, "There are exactly 39 figures in that group."

B. One soldier says, "No, there are 38."

C. Equally reliable or unreliable.

Go on to the next page.

Reminder--mark as follows:

A. The first is more reliable.
B. The second is more reliable.
C. They are equally reliable or unreliable.

40. A. The mechanic takes his glasses back from the health officer and makes a count. "Yes, there are 39 of them," he says.

B. The soldier repeats, "There are only 38."

C. Equally reliable or unreliable.

The people around the fire get up and start toward the village. You quickly take your small party to a place on a nearby hill. There you can see the village without being seen. You want to find out whether this is a friendly village, whether the explorers are prisoners, and how many explorers are left.

The mechanic writes down what people say they see.

41. A. One soldier counts the people as they move around in the village and announces, "Only 32 came back from the fire."

B. Another soldier says, "You must have missed two. I counted as they filed past the big hut. 34 came back. None of them came back any other way, I believe."

C. Equally reliable or unreliable.

42. A. The anthropologist reports, "One of them had on a green hat when they returned from the fire. But he's the only one. I watched them carefully as they went by the big hut."

B. The health officer says, "I think there are two with green hats. First I saw one on the left. Later I saw one way over on the right."

C. Equally reliable or unreliable.

43. A. A soldier says, "Five times in the last minute the one in the green hat has talked to someone and pointed. Immediately that person has run off in the direction he pointed."

B. "He must be the leader," added the soldier.

C. Equally reliable or unreliable.

44. A. "Look. Captain Sardus and two other explorers are coming up to the one in the green hat, who is pointing to the big hut. The one in the green hat is ordering them to go in."

B. "Here come Sergeant Edema and one other explorer. The one in the green hat is pointing to the big hut. They're going in also," added the anthropologist.

C. Equally reliable or unreliable.

Go on to the next page.

Reminder--mark as follows:

A. The first is more reliable.
B. The second is more reliable.
C. They are equally reliable or unreliable.

45. A. Several more groups of explorers enter the hut. The health officer asks the mechanic, who has been keeping a record, "How many do you think are in there now? I've told you each time one went in. I think there are 13."

B. The mechanic replies, "According to my record, there are 14."

C. Equally reliable or unreliable.

46. A. The anthropologist states, "That one with the green hat is going into the hut to the right of the big hut. Three others are following him in."

B. The health officer says, "Look, here comes another with a green hat. So the one in there is not the leader, since there are two. Let's check the people who go into the hut."

C. Equally reliable or unreliable.

47. A. The anthropologist has been describing the people as they go in, trying to get some idea of what they might be like. He states, "18 people went into that hut."

B. The mechanic disagrees, "According to the record of what you have said, only 17 went in."

C. Equally reliable or unreliable.

48. A. The anthropologist then looks over to the large hut and says, "Do you see those two men? Perhaps they are sentries guarding the explorers. Oh, look! They're changing. The walking one stops about 15 feet from the door and then the one standing by the door walks over to him."

B. The health officer says, "Yes, I've watched them make ten changes now. But you have the order wrong. The man by the door leaves his post before the the walking one reaches the point of change."

C. Equally reliable or unreliable.

49. A. The mechanic, who also has been watching, says, "I think the health officer is right."

B. The anthropologist says, "I think he's wrong."

C. Equally reliable or unreliable.

Go on to the next page.

Reminder--mark as follows:

A. The first is more reliable.
B. The second is more reliable.
C. They are equally reliable or unreliable.

50. A. One soldier says, "Oh, look at the tall sentry. He has an odd way of walking. He brings his left hand across almost to his right shoulder before his left foot touches the ground."

B. Another soldier replies, "It is odd. I've been watching him for about five minutes though, and you have the order reversed. He brings his left hand across after his left foot touches the ground."

C. Equally reliable or unreliable.

Go on to the next page.

Part II, Section A - What Can Be Done?

Your party discusses what can be done to rescue the explorers, and tries to reason things out.

For these last two sections of the test, it is all right to return to an item after you have left it.

In each of the items in this section, you must decide what follows from the reasoning. Do not judge whether the reasons are true. Just decide what would follow from them, if they were true.

Mark A, B, C, or leave it blank if you don't know. Consider each item by itself. Here is an example:

51. The mechanic says, "If these beings are people from earth, then they will welcome us. Certainly they are people from earth."

Which follows? Pick only one.

A. These beings will not welcome us.
B. These beings are not from earth.
C. These beings will welcome us.

Which did you mark? You should have marked C. Whether C is true or not, it follows from what the mechanic said. Go on to the rest. There is one best answer to each item.

52. "If these beings are from the earth, then another space ship must have landed here on Nicoma. These beings definitely are people from earth."

Which one follows?

A. Another space ship has landed on Nicoma.
B. These beings are not from the earth.
C. Another space ship has not landed on Nicoma.

53. "If these beings are from the earth, then another space ship must have landed on Nicoma. But no other space ship has landed on Nicoma, in my opinion."

Which one follows?

A. Another space ship has landed on Nicoma.
B. These beings are not from the earth.
C. These beings came here by mistake.

54. "Whenever sentries are used, two groups are unfriendly. Those two men are sentries."

Which one follows?

A. The two groups are friendly.
B. The two groups are unfriendly.
C. If groups are unfriendly, sentries are used.

55. "All earth people are able to talk. These are earth people."

Which one follows?

A. They are able to talk.
B. They are unable to talk.
C. If people are able to talk, they are from the earth.

Go on to the next page.

56. "If a group of beings is approached in a friendly manner, the group will be friendly. This group of beings is not friendly to the explorers."

Which one follows?

A. The explorers approached them in a friendly manner.

B. The explorers did not approach them in a friendly manner.

C. This group of beings was unfriendly before the explorers approached them.

57. "If a group from earth lands on a planet, the landing is announced throughout the world in newspapers. No landing on Nicoma was announced, except for our landing and the landing of our explorers."

Which one follows?

A. If the newspapers announce a landing, then there has been a landing.

B. The group of beings is from the earth.

C. The group of beings is not from the earth.

58. "A group that is really unfriendly to outsiders will starve them. Our explorers certainly are not starved."

Which one follows?

A. Our explorers are really friendly.

B. The group of beings is really unfriendly to our explorers.

C. The group of beings is not really unfriendly to our explorers.

59. "This group is friendly to our explorers. If a group is friendly to another group of beings, it will not put them in prison."

Which one follows?

A. Our explorers were not put in prison.

B. Our explorers were put in prison.

C. Unfriendly groups try to put each other in prison.

60. "There have been only two announcements of landings on Nicoma--our landing and the landing of our explorers. All landings on other planets of people from the earth are announced in the newspapers of the earth."

Which one follows?

A. The group of beings is not from the earth.

B. The group of beings is from the earth.

C. The newspapers never make mistakes.

61. "If a group is friendly to another group of beings, it will not put them in prison. A group that is not in prison would be out working on a day like this. Our explorers are not out working."

Which one follows?

A. The group is friendly to our explorers.

B. Unfriendly groups try to put each other in prison.

C. The group is unfriendly to our explorers.

62. "Look, one of our explorers climbed out a window and started to run away. He stopped running and put his hands up when a sentry aimed a rifle at him and shouted. A friendly group would let its guests leave."

Which one follows?

A. Unfriendly groups put their guests in prison.

B. This group of beings is very careful.

C. This group of beings is unfriendly.

Go on to the next page.

63. "If we can talk to our explorers, we can find out for sure if these beings will make peace. We can talk to our explorers by sneaking in the back when the sentries change places."

Which one follows?

A. We can find out for sure if these beings will make peace.
B. We can not find out for sure if these beings will make peace.
C. We can not sneak in the back if the sentries are very careful.

64. "If they are from the earth, they are well-armed. If they are well-armed, they must be taken by surprise. They obviously are from the earth."

Which one follows?

A. They are poorly armed.
B. They can be approached in peace.
C. We must surprise them.

65. "If we attack them, we will kill some. If we kill some, we will lose information about Nicoma. Now we must not lose any information about Nicoma."

Which one follows?

A. We must attack.
B. We must kill some of them.
C. We must not attack.

Go on to the next page.

Part II, Section B - Reporting Back and Deciding What to Do

After watching the village for about an hour, you lead your party back to the main camp. You report to your leader. In making your report, you take certain things for granted. These things fill the gap in your reasoning. Here is an example:

66. "The explorers can't escape, because they can't break down the walls of the stone hut."

Which is taken for granted?

A. The explorers can jump out the window.
B. The guards are alert.
C. All ways of escape, except through the walls, are impossible.

What is the answer? The answer is C. It would fill the gap in the reasoning. A and B would not fill the gap. Mark C for number 66. There is one best answer to each of the following items.

67. "Since our explorers are prisoners, we can not talk to them without being discovered.

Which is taken for granted?

A. In general prisoners can not be talked to, unless their guards know about it.
B. In general, if we talk to people, they will tell others about it.
C. In general, if we talk to people, they will not tell others about it.

68. "If we talk reasonably to those people, they'll release our explorers. After all, those people are human beings and the release of our explorers would help humanity."

Which is taken for granted?

A. When you talk reasonably to human beings, they will act in a way to help humanity.
B. Anything that human beings do is intended to help humanity.
C. You have to talk reasonably to human beings in order to get them to do something.

69. "The shorter of the two people wearing green hats is a female. I know because I saw her long hair when she removed her hat."

Which is taken for granted?

A. All females have long hair.
B. Only females have long hair.
C. A person wearing a green hat is likely to be a female.

70. "Since about half of the villagers had very short hair, I think that at least half are male."

Which is taken for granted?

A. Half are female.
B. All males have short hair.
C. Only males have short hair.

71. "If at least half of them are men, then in a fight we will have to fight at least half of them."

Which is taken for granted?

A. Women are not fighters.
B. Mean are fighters.
C. We can not beat them all, if they are all fighters.

Go on to the next page.

72. "We need not worry about more than 10 of them at a time, since there are only 10 guns."

Which is taken for granted?

A. Guns can hurt us.
B. Knives can not hurt us.
C. Only guns can hurt us.

73. "They have only 10 guns. I know because each sentry had one gun and 8 guns were stacked in the middle of the village. That's all that could be seen."

Which is taken for granted?

A. All guns that they have are in plain sight.
B. They do not carry guns under their animals skins.
C. Guns are their only weapons.

74. "The villagers did not have any scouts out. This I can tell because we saw none, and we looked carefully."

Which is taken for granted?

A. Scouts are used only by people who want somebody to investigage for them.
B. Scouts show themselves to people who are alert for them.
C. If you see a scout, then he has been careless.

75. "The villagers must not know of our presence, since there are no scouts out watching us."

What is taken for granted?

A. If a group knows of the presence of another group which is possibly unfriendly, the group will have scouts out watching the other group.
B. If there are scouts out watching, then the group from which they come knows of the presence of another group.
C. If a village sends out scouts, the villagers suspect trouble.

76. "The villagers are not from the United States, because we have not heard of any other landings on Nicoma by people from the United States.

Which is taken for granted?

A. All landings on planets are announced.
B. All landings by United States people on planets are announced to other explorers from the United States.
C. Explorers from the United States do not hear of landings by explorers from other countries.

<u>END OF TEST</u>. If you have time, you may go back and check over your answers, but only in the last two sections (Items 51 and 76). Do not guess wildly. Answer a question if you <u>think</u> you know the answer, but are not sure.

Here's the rest of the story: The explorers prepared for an attack and sent a truce party to talk to the villagers. The villagers, who came by mistake to Nicoma in a space ship from the earth, made peace.

ATTITUDES TOWARD SCIENCE AND SCIENTIFIC CAREERS

Reaction Inventory*

Name ______________________________ School ________________
First Last

Instruction: Please give your reactions to the following list of statements regarding science, scientists, and scientific careers. Work rapidly. Record your first impressions---- the feeling that comes to mind as you read the item. Place your answers on the answer sheet. Do not write in the booklet.

Draw a circle around AA if you completely agree with the item.
Draw a circle around A if you are in partial agreement.
Draw a circle around N if you are neutral.
Draw a circle around D if you partially disagree.
Draw a circle around DD if you totally disagree.

Example:

AA A N D DD 100. In the springtime Paris is more beautiful than New York. (Since A is circled, this indicates that you are in slight agreement.)

AA A N D DD 1. Science is not sufficiently appreciated by most people.

AA A N D DD 2. Science is a systematic way of thinking.

AA A N D DD 3. Scientists are seldom concerned with their working conditions.

AA A N D DD 4. The development of new ideas is the scientist's greatest source of satisfaction.

AA A N D DD 5. Friends often discourage girls from taking high school science courses.

AA A N D DD 6. Science and technology are essential to the development of present-day cultures.

AA A N D DD 7. Increased radiation resulting from bomb tests is a threat to civilization.

AA A N D DD 8. Scientists are too narrow in their views.

AA A N D DD 9. Industries use research as a means to improve their economic position.

AA A N D DD 10. The application of scientific knowledge to the development of new industries enriches society.

AA A N D DD 11. The President's cabinet should be enlarged to include a Secretary of Science.

*From Attitudes of Certain High School Seniors Toward Science and Scientific Careers, Bureau of Publications, Columbia University, New York, N. Y., 1959. Used by permission of the author, Hugh Allen, Jr.

Reaction Inventory (continued)

AA A N D DD 12. The scientist will make his maximum contribution to society when he has freedom to work on problems which interest him.

AA A N D DD 13. A scientist might aptly be described as a nonconformist.

AA A N D DD 14. Scientists should be looked upon as "subjects for suspicion."

AA A N D DD 15. Scientific investigations are undertaken as a means of achieving economic gains.

AA A N D DD 16. To become a scientist requires superior ability.

AA A N D DD 17. Science requires creative activity.

AA A N D DD 18. Scientists are willing to change their ideas and beliefs when confronted by new evidence.

AA A N D DD 19. Scientists have unusually intelligent mothers.

AA A N D DD 20. Scientists are "longhairs."

AA A N D DD 21. The complexity of science hides its cultural values.

AA A N D DD 22. Modern science is too complicated for the average citizen to understand and appreciate.

AA A N D DD 23. Scientists possess too much power in our society.

AA A N D DD 24. Decisive economic, political, and social processes are greatly influenced by science.

AA A N D DD 25. It is undemocratic to favor exceptional scientific talent.

AA A N D DD 26. The monetary compensation of a Nobel Prize winner in Physics should be at least equal to that given populat entertainers.

AA A N D DD 27. Hazards created by the increased use of radioactive materials make scientific work less attractive than previously.

AA A N D DD 28. Scientists are shy, lonely individuals.

AA A N D DD 29. Loyalty checks and security clearances have seriously interfered with the work of scientists.

AA A N D DD 30. For me, training for a career in science is not worth the time and effort required.

AA A N D DD 31. Science is primarily a method for inventing new devices.

Reaction Inventory (continued)

AA A N D DD 32. Scientists are more emotional than other people.

AA A N D DD 33. Girls have very little mechanical aptitude, and therefore should not consider scientific careers.

AA A N D DD 34. Scientists are honored persons who stand very high in popular prestige.

AA A N D DD 35. To appreciate modern society fully, a person must understand the importance of science.

AA A N D DD 36. Scientists are an "odd" lot.

AA A N D DD 37. Science without mathematics is impossible.

AA A N D DD 38. Science is the greatest unifying force among nations.

AA A N D DD 39. Maintenance of scientific work is essential to national survival.

AA A N D DD 40. The use of scientific achievement is often hampered by selfish individuals.

AA A N D DD 41. Scientific work is boring.

AA A N D DD 42. Scientific activity is greatly influenced by culture.

AA A N D DD 43. The free flow of scientific information among scientists is essential to scientific progress.

AA A N D DD 44. I don't have the intelligence for a successful scientific career.

AA A N D DD 45. The winning of the esteem of his associates is one of the main incentives for the scientist.

AA A N D DD 46. Scientific findings always lead to final truths.

AA A N D DD 47. Scientists are as concerned as are other groups with the policies of the company for which they work.

AA A N D DD 48. Industrial developments are based more on practical experience than on laboratory research.

AA A N D DD 49. The scientist can expect to accumulate little wealth as compensation for his work.

AA A N D DD 50. Science is a man's world, there is little room in it for women.

AA A N D DD 51. Science is primarily responsible for the frequent changes which occur in our manner of living.

AA A N D DD 52. Scientists are "eggheads."

Reaction Inventory (continued)

AA A N D DD 53. Scientific work requires long years of labor and self-discipline.

AA A N D DD 54. A great research scientist is little concerned with the practical applications of his work.

AA A N D DD 55. Scientists are communistic.

AA A N D DD 56. Science is an attitude towards life and environment.

AA A N D DD 57. Our foremost scientists are primarily concerned with their own thoughts and ideas.

AA A N D DD 58. Science has done little for the average citizen.

AA A N D DD 59. Scientific truths are usually found by persons seeking economic gain.

AA A N D DD 60. The neglect of basic scientific research would be the equivalent of "killing the goose that laid the golden eggs."

AA A N D DD 61. Science receives too little serious attention in the mass media.

AA A N D DD 62. Scientists today are subject to too many governmental restrictions.

AA A N D DD 63. The engineer serves a more practical purpose in society than does the research scientist.

AA A N D DD 64. There is much self-satisfaction to be received from work as a scientist.

AA A N D DD 65. A scientist's life is full of adventure.

AA A N D DD 66. The average American home discourages girls from scientific careers.

AA A N D DD 67. Universities do little scientific research that is of immediate practical value.

AA A N D DD 68. Scientists do not need the physical stamina necessary for most other work.

AA A N D DD 69. Science helps us to understand our environment.

AA A N D DD 70. Scientific concepts and discoveries often bring about new sociological problems.

AA A N D DD 71. Scientists are against formal religion.

AA A N D DD 72.* "Practical" politicians and business men disregard the advice of scientists.

AA A N D DD 73. Scientists often have physical deformities which render them unfit for other work.

Reaction Inventory (continued)

AA A N D DD 74. Science and its inventions have caused more harm than good.

AA A N D DD 75. The social environment of the United States is hostile to the development of scientific talent.

AA A N D DD 76. One cannot have a normal family life and be a scientist.

AA A N D DD 77. The bulk of scientific research is carried on by devoted men and women without regard for their personal living or social relations.

AA A N D DD 78. Public interest in science is essential to the maintenance of scientific research.

AA A N D DD 79. Most of the basic scientific research done in our country is carried on by industry.

AA A N D DD 80. Many specific findings in science contradict the laws of God.

AA A N D DD 81. American scientists are largely responsible for our country's status among nations.

AA A N D DD 82. Scientists are essentially magicians, making two blades of grass where one grew before.

AA A N D DD 83. Industrial research is often carried on by teams of scientific workers.

AA A N D DD 84. Scientific work is monotonous.

AA A N D DD 85. The working scientist believes that nature is orderly rather than disorderly.

AA A N D DD 86. The modern world is dominated by science.

AA A N D DD 87. Scientists as a group are often condemned for the unpopular ideas and activities of a few fellow workers.

AA A N D DD 88. Scientists are often willing to sacrifice the welfare of others to further their own interests.

AA A N D DD 89. Scientists are usually unsociable.

AA A N D DD 90. Curiosity motivates scientists to make their discoveries.

AA A N D DD 91. The chief reward in scientific work is the thrill of discovery.

AA A N D DD 92. In high school, boys receive more encouragement to take science courses than do girls.

AA A N D DD 93. Americans place greater value on the practical applications of scientific discoveries than on the discoveries themselves.