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ABSTRACT

Reported is a study made to determine the feasibility of teaching science by utilizing selected concepts related to the social and historical development of science and selected concepts related to atomic energy. Instructional materials included textual materials developed by the investigator, a test, a series of slides, and four motion pictures. The investigator taught the unit to two different high school populations (one, 107 students; the other, 76 students). Mean gains for the subtest and total test were significant for both groups. Student responses indicated a majority expressed a positive opinion toward the interest-producing potential of this unit. The report includes the investigator's research procedure and results presented in tabulated form. A copy of the evaluation instrument, the student response questionnaire, and a bibliography are included. (Author/EB)

Technical Report No. 303

# THE FEASIBILITY OF TEACHING SCIENCE VIA A SOCIO-HISTORICAL APPROACH PART I

Report from the Project on Elementary Science--Man and the Environment

by Michael Lawrence Agin

Milton O. Pella
Principal Investigator

Part II, the classroom materials, has been published as Practical Paper No. 303



Wisconsin Research and Development
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## STATEMENT OF FOCUS

Individually Guided Education (IGE) is a new comprehensive system of elementary education. The following components of the IGE system are in varying stages of development and implementation: a new organization for instruction and related administrative arrangements; a model of instructional programing for the individual student; and curriculum components in prereading, reading, mathematics, motivation, and environmental education. The development of other curriculum components, of a system for managing instruction by computer, and of instructional strategies is needed to complete the system. Continuing programmatic research is required to provide a sound knowledge base for the components under development and for improved second generation components. Finally, systematic implementation is essential so that the products will function properly in the IGE schools.

The Center plans and carries out the research, development, and implementation components of its IGE program in this sequence: (1) identify the needs and delimit the component problem area; (2) assess the possible constraints--financial resources and availability of staff; (3) formulate general plans and specific procedures for solving the problems; (4) secure and allocate human and material resources to carry out the plans; (5) provide for effective communication among personnel and efficient management of activities and resources; and (6) evaluate the effectiveness of each activity and its contribution to the total program and correct any difficulties through feedback mechanisms and appropriate management techniques.

A self-renewing system of elementary education is projected in each participating elementary school, i.e., one which is less dependent on external sources for direction and is more responsive to the needs of the children attending each particular school. In the IGE schools, Center-developed and other curriculum products compatible with the Center's instructional programing model will lead to higher morale and job satisfaction among educational personnel. Each developmental product makes its unique contribution to IGE as it is implemented in the schools. The various research components add to the knowledge of Center practitioners, developers, and theorists.

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****

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ABSTRACT

The purpose of this study was to determine the feasibility of teaching science via a socio-historical approach utilizing selected concepts related to the social and historical developments of science and selected concepts related to atomic energy. The criteria used to assess the success of the approach were:

1. A significant increase in subject matter knowledge possessed by the students participating in the study.

2. A high level of student interest toward the socio-historical approach as indicated by the responses of the students to an interest questionnaire.

3. An increase in student understanding of knowledge related to

a. science and scientists,

b. science-society interrelationships, and

c. the atom and atomic energy.

The instructional materials for the study included a) 12 chapters of textual materials developed by the

investigator, b) a test based on the text, c) a series of slides, and d) four selected motion picture films. The investigator, who utilized a lecture-discussion technique with an accompanying slide presentation, taught the instructional unit to two different high school populations during two 14-day periods of instruction. The populations included in the study included 107 twelfth-grade students in American Problems classes (School A) and 76 tenth-, eleventh-, and twelfth-grade students in Chemistry classes (School B).

A 90-item multiple choice test, administered as a pretest and posttest to both groups, yielded three subtest scores--science and scientists, science-society interrelationships, and the atom and atomic energy--and a total score for each student. Mean gains--the difference between pretest and posttest class mean scores--for the subtests and total test were tested statistically and found to be significant for both schools. Correlation coefficients of individual scores on the test and IQ did not reveal any consistent pattern of relationship.

Student responses to a questionnaire indicate that a majority of the students in both schools expressed a positive opinion toward the interest producing potential of the unit and indicated that the reading material was at least at the same level of difficulty as material experienced in science classes. In addition, at least 83% of the students of School A and 91% of School B felt that the unit increased their understanding of a) science and scientists,

b) science-society interrelationships, and c) the atom and atomic energy.

On the basis of the conditions of the study, namely the procedures utilized and the nature of the populations included, it was concluded that teaching via a socio-historical approach is feasible since the performance of the students met the criteria for acceptance.

# CHAPTER I. THE PROBLEM

## Introduction

The post-Sputnik years have been characterized by an increased emphasis on the processes (methods) and products (concepts) of science and an almost complete exclusion of teaching the interrelationships of science and society. In a majority of the new curricula science is taught in a "social vacuum." The statement by Thomas (1954) summarizes this state of affairs:

> The training now given to students of the natural sciences is generally planned, consciously or unconsciously, with a view to the production of professional scientists who will spend their lives at research or teaching.
>
> . . . . . . . . . . . . . . . . . . . . . . . . .
>
> Present-day science students have been specialists since the age of sixteen or earlier: they have very limited knowledge about the world and of the behavior of man,...they know little about real history, and are scarcely sensible of their debt to the past.

Although there is a greater emphasis on science the percentage enrollment in many high school science courses has decreased while the total high school enrollment has increased. For example, the percentage enrollment trend in Iowa has decreased over an eight year period. As

Troxel and Yager (1968) state:

> ...when comparing the gain in science enrollment over the eight years mentioned [1958 to 1966] with the normal increase in secondary school enrollment, it is readily apparent that the percent of students taking science courses in Iowa is actually decreasing in relation to the expected increase.

These declines coupled with the trend away from socially oriented science curricula have alarmed many foresighted scientists and science educators. They are concerned with the widening gap between science and society and the implications this schism holds for the future. As Hurd (1970) states:

> We live in an era most accurately described by its scientific and technological progress. It is a period in history not like any we have known before....The scientific and technological revolutions over the past quarter of a century more closely resemble a cultural mutation. However, the influence of science upon our economy, upon international politics, and upon other fields of inquiry is not obvious to most people [italics mine].
>
> . . . . . . . . . . . . . . . . . . .
>
> A serious credibility gap, greater than we have dared to admit, has developed between the school science curriculum and the present character of our society. As science becomes broadly integrated into all phases of our culture its significance as a part of general education becomes more important. However, a majority of adults are unaware of or are misinformed about the meaning of science and its influences on the material, social, and intellectual life of

> our time. As a result they have little insight into the meaning of problems which plague mankind today--environmental pollution, poverty, disease, overpopulation and the management of leisure.
>
> . . . . . . . . . . . . . . . . . . .
>
> ...the subject matter of school science courses has been increasingly restricted to conveying a notion of the structure and research techniques of specific disciplines. The curriculum has not considered in any direct way the relation of science to the affairs of man, the actualities of life, and the human condition. The scientific enterprise as a part of general education has meaning only in a cultural and social context.

This point of view is also supported by Roberts (1961):

> The position of the scientists in society has improved markedly during the last two decades....Scientists have achieved a higher level of respect by society than at any time in history ....And yet the gulf of understanding between scientists and the rest of society is huge and dismaying.

He amplifies this concern with:

> ...science is too crucial a part of the life on this planet for it to be beyond the understanding, criticism and control of democratic people.
>
> . . . . . . . . . . . . . . . . . . .
>
> ...education must bridge the gap between scientists and layman, between two parts of society which,...understand each other so little. Until the gap is bridged, democratic societies will scarcely be able to protect themselves from the danger that arises from the assumption of too much power by those that wrap themselves in the cloak of scientific "wisdom."

The question is, "What should be the broad goal of science teaching?" In a succinct and forceful statement Gatewood (1968) summarizes the thoughts of many scientists and science educators when he states:

> In a society that is scientifically and technologically oriented as ours is today, all students should be broadly educated in science, in its processes, its products, its philosophy, and its impact on society....The single most important goal of school science must be to prepare scientifically literate citizens for the future.

Hurd (1970) proposes that science education should develop a scientifically enlightened citizenry. He states:

> The broad goal of science teaching ought to foster the emergence of an [scientifically] enlightened citizenry, capable of using the intellectual resources of science to create a favorable environment that will promote the development of man as a human being.

He is primarily concerned with science in a matrix of general education. He adds:

> The significance of a science concept for general education is more its meaning for problems of human living than its importance for basic research. It should be vital for the advancement of the individual rather than for the promotion of science.

In conjunction with the discussion of science education (present and future) consideration must be given to the responsibility of science education for the future. In regard to the responsibility of science teachers and science educators Pella (1969) states:

> As science teachers, our task is to develop programs and practices that reflect our knowledge of the way science influences society, the way society influences science, and the importances of these knowledges to every citizen who wishes to participate actively in making social decisions that are auspicious when judged on the basis that the benefit to be derived will be significantly greater than the risks implied. The management of the environment of man by man must assume a posture for the future as well as the present.

If the goal of science teaching is the "scientifically literate citizen"(NSTA, 1964) or "the scientifically enlightened person" (Hurd, 1970) capable of weighing decisions on the basis of "benefits versus implied risk" (Pella, 1969), then what can be done to secure the proper finished product? In answer to this, Hurd (1970) states:

> What is needed now is a curriculum designed to bring about an understanding of the scientific and technological enterprises and the ramifications of social integration of both.
>
> ...with a focus upon the broader perspective of scientific enlightenment embedded in a social context, we have the potential of moving school science courses from their present isolation into the "real world" of the student.
>
> . . . . . . . . . . . . . . . . . . .
>
> A general education in the sciences should make it possible for people to appreciate the worthiness of the scientific enterprise and to use its achievements....This means that the present science curriculum will need

> to be changed to provide a wider picture of science.
> It will require reordering the subject matter of science, placing it within a cultural context, and demonstrating more concern for human betterment. The implementation of this program should be phase two of the current curriculum reform.

Rabinowitch (1958) states:

> In high school teaching, the ethical and moral aspects of science, the relation of scientific truth to the general system of human values, and the responsibility of science, and scientists for the future of society, must be impressed on students.

With these thoughts in mind, this investigator has developed a teaching unit designed for use in guiding instruction relative to the social and historical developments of science utilizing a central theme, <u>the development of atomic energy and its social implications</u>. The attempt here is to investigate whether the teaching of science, utilizing a socio-historical approach, is realistic in teaching the products and processes of science in addition to the interactions of the encompassing society. It is opined that there is some portion of the high school population that may wish to learn about the way in which science and society interact.

## Statement of the Problem

To determine the feasibility of teaching science via a socio-historical approach utilizing selected concepts related to the social and historical development of science and selected concepts related to atomic energy.

## Assumptions Underlying the Study

The study is based upon the following assumptions:

1. Science and society are interrelated.

2. Some understanding of the science-society interrelationships will help individuals to become more scientifically literate citizens.

3. Interrelationships between science and society can be integrated with scientific concepts and taught in one coordinated unit.

4. There exists a need for a more effective means of learning the interrelationships of science and society.

5. There exists a segment of the high school population that will benefit from a socio-historical approach to learning.

## Criteria for Acceptance of Feasibility

1. There shall be a significant increase in subject matter knowledge related to

   a. science and scientists,

   b. the interrelationships of science and society, and

c. the atom and atomic energy, possessed by students participating in the study as indicated by comparison of pretest and posttest scores.

2. There shall be a high level of student interest toward the socio-historical approach as indicated by the responses of students to an interest questionnaire.

3. There shall be, in the opinion of the students, an increase in student understanding of knowledge related to

a. science and scientists,

b. the interrelationships of science and society, and

c. the atom and atomic energy as indicated by the responses of the students to a questionnaire.

## Definition of Terms

1. For the purpose of this study, science is defined as a social activity...a set of behaviors taking place in human society (Barber, 1952).

2. Concept is defined as a summary of the essential characteristics of a group of ideas and/or facts that epitomize important common features or factors from a larger number of ideas (Pella, 1966).

3. The socio-historical approach to science instruction is defined as teaching the development in a

socio-historical setting of certain selected concepts in science which have exhibited a high level of social significance (Boles, 1968).

4. A societal implication is a direct or implied relationship between a scientific or technological development and one or more facets of society (O'Hearn and Pella, 1967).

## CHAPTER II. RELATED LITERATURE

### The Historical Approach As a Method of Science Instruction

The use of a historical approach to science instruction has generated much interest among scholars since World War II. Some scientists and science historians have been interested in the use of historical materials in science instruction for the "layman" or "nonscientist." According to Conant (1947) for:

> nine people of ten the historical method would yield more real understanding of a complex matter.

However, others have felt that the history of science is of importance to all people. As Cohen (1952) states:

> From the strict point of view of the practicing scientists, ..., the history of science may be less essential than, say, mathematics. Yet I firmly believe that the history of science is useful to the scientists as it is to the non-scientist.

In General Education in Science (1952) scientists and science historians such as Cohen, French, Fuller, Kilgour, and Nash, present arguments in support of a historical approach to science instruction. As Nash (1952) states:

> It seems to us that a major step toward the understanding of science can be

> taken through an intensive study of the lessons implicit in selected episodes of scientific history.

Ihde (1953) maintains that the historical approach to science instruction enables the student to see knowledge of the subject unfolded before his eyes and helps to show that science is part of the human enterprise. He states:

> The historical approach to science instruction is merely sound teaching since it enables the student to see knowledge on the subject revealed in the manner in which it unfolded before the eyes of the great investigators.
>
> . . . . . . . . . . . . . . . . . . .
>
> Historical material also helps show that science is part of the human enterprise. This point is often missed when the course becomes solidly loaded with factual and theoretical materials.

In the past few decades science teachers and developers of science curricula have eliminated more and more of the historical aspects of science from their science materials. According to Ihde (1953), this trend is prevalent at the college and high school level. It is justified in the name of progress and by the attitude that the old must give way to the new. In response to this attitude he states:

> This attitude is a dangerous one. It easily leads to the belief that only the new is important. However, the new often represents a development in applied science and leads to the belief that investigations must be practical. There is a failure to recognize that new developments have an earlier and more fundamental background. This

> recognition is more important than an aura of up-to-dateness.
>
> . . . . . . . . . . . . . . . . . . . . . . . .
>
> Chemistry, for example, did not start out with a structural atom as some of our present-day textbooks do. The structural atom is a development of the past half-century and could not have been satisfactorily conceived before that time.
>
> . . . . . . . . . . . . . . . . . . . . . . . .
>
> We expect students to by-pass those essentials that the practicing chemists had to master before they could proceed. It would seem that students can most easily master the subject in the manner that it was mastered by the best investigators in the field.

If the historical approach to science instruction is desirable, then how should it be presented? Ihde (1953) suggests several alternatives:

> 1. A random study of history is possible but it is not apt to be very successful. The reasons are evident.
> 2. A second possibility is the history of science approach....[Ihde discourages the use of this alternative in secondary school] In order to fruitfully study the history of science the student must have a background of science.
> 3. ...the most useful one, is the case history.

Of the alternatives listed by Ihde (1953) the case history approach to science teaching is most similar to the socio-historical approach used in this study.

The Case History Approach to Science Instruction

Any discussion of case histories as an instructional approach must refer back to Professor Christopher C. Langsdell, who initiated the use of cases in the study of law in the 1870's at Harvard (Klopfer, 1964). This method of instruction has been successfully employed in professional education in other fields, in particular medicine, social work, and business administration.

In 1946, Conant proposed the use of case histories in science instruction to convey to the students a deeper understanding of science. His proposal was in response to the concern then felt by a number of college educators for restructuring general education courses in science. This suggestion resulted in the development of the Harvard Case Histories in Experimental Science (1957): a series of specially-prepared case histories used in a general education course at Harvard.

According to Klopfer (1964) in each of these Harvard Case Histories:

> the evolution of a major scientific idea is followed in detail through the original writings and activities of the scientists involved....these case histories exemplify and direct students' attention to important understandings about the processes of science, the scientific enterprise, and the characteristics of scientists.

The pioneering efforts of Conant and his associates encouraged the development of similar case histories for use in science teaching at the secondary school level. In 1956 work began on several preliminary case histories for classroom trial at the secondary school level which eventually resulted in an experimental edition of History of Science Cases for High School (HOSC) (1960). In this series of cases the attempt was not to teach history, but to use the historical approach to illustrate and promote the development of important ideas concerning science and scientists. According to Klopfer and Watson (1957):

> ...a case is concerned with the development of new concepts, it not only involves the final results of scientific inquiry, but stresses the scientists who were involved, the information available to them, their search for better facts and explanations, and the intellectual and social climate in which they worked. Thus, past scientific accomplishments appear as part of our total intellectual and social history. Emphasis upon the development of concepts allows transfer of the ideas stressed to current and future scientific efforts.

The HOSC have been designed for use as separate units of instruction within existing science courses in the secondary school. Each HOSC unit is an illustrated booklet, containing historical narrative, quotations from scientists' original papers, pertinent student experiments and activities, marginal notes and leading questions for discussion. The objectives of instructions using the HOSC

Approach generally include the understanding by students of scientists as individuals, of the aims of science, and of the processes of science.

What are some of the generalizations about science and scientists that students may be expected to derive from studying a case history? According to Klopfer (1964), in addition to subject matter objectives, certain generalizations about science and scientists comprise the more significant specific objectives for the several HOSC units. This latter group of objectives includes student understanding of such ideas concerning science and scientists as the following:

> 1. A scientist's observation and interpretations are influenced by the concepts he holds and by his background.
> 2. New apparatus and new techniques are important in making possible new experiments and the exploration of new ideas.
> 3. A scientists must develop suitable techniques to make correct and reliable identifications of the substances he observes.
> 4. Scientists are unique individuals possessing a wide range of personal characteristics and abilities.
> 5. Science is an international activity.
> 6. Science is different from applied science or technology.
> 7. The general state of technology and of the culture outside of science often influences the development of science.
> 8. Free communication among scientists is the lifeblood of science. Scientists communicate with one another through meetings, jounals, books, and personal correspondence.

> 9. There is a continual interaction of ideas and experiments in scientific work. Imaginative individuals are needed to provide hypotheses and to plan experiments for testing them.
>
> 10. New observations have a trigger effect: they shake up established con- concepts and lead to new hypotheses and new experiments.
>
> 11. Scientific laws and theories are used to "explain" natural phenomena. A scientific law is a generalized statement of observed empirical relationships. A scientific theory, consisting of a few postulates or assumptions, is a statement of a scientist's views concerning some part of the natural universe.
>
> 12. The physical world does not change, but our understanding of it changes as we describe it in different terms.

However, the intended purpose of science case histories has not been fulfilled completely. As Shirley (1951), who constructively criticizes Conant's Harvard Case Histories, states:

> There is a brief attempt in each volume to place the experiment discussed into the theoretical background of its time, but there is little effort made to show the way in which it grew out of a particular need or a particular situation. As a result, the case histories by themselves at first glance appear to reinforce the nineteenth-century view of science as a series of steps in which the inherent genius of each great scientist advanced men's knowledge by bounds, rather than the twentieth-century view of science as evolutionary with many social and intellectual factors combining to contribute to--if not demand--the new discovery in its time and place.

Shirley (1951) suggests that it is necessary to begin with social affairs and work toward an interest in science and its impact on society but questions the possibility of a single course being able to integrate science with the humanities and social science. Shirley suggests that this integration should be a balanced whole. He states:

> Integration of this nature can be achieved only when general education courses of the humanities, social sciences, natural sciences, and biological sciences are arranged into an integrated pattern of the whole, with each course of the sequence based on those which have gone before, and the interrelations of the various fields constantly stressed in all....there should be a balance and a maturity in each segment of what is to be a balanced whole.

## The Socio-Historical Approach to Science Instruction

In contrast to the case history approach, the socio-historical approach places stress on the interrelationships of science and society in addition to teaching for an understanding of the scientific enterprise and its products. It goes beyond the more limited case history approach by considering social implications as science interacts with society.

Rabinowitch (1958) sets a philosophical basis for a socio-historical approach when he observes:

> ...what is required is not heaping one scientific course upon another, or stuffing existing ones with more and

> more subject matter....What is needed, instead, is a careful selection of material from key areas of science, suitable for demonstration of the methods by which science approaches and explores nature, of the ways in which it arrives at its general concepts; of the types of questions it asks and types of answers it receives,...so that, on leaving school [high school] , students will comprehend the potentialities as well as the limitations of the experimental method.
>
> . . . . . . . . . . . . . . . . . . .
>
> Science education on the high school level should leave open to every intelligent student the option of entering,..., a field of science, not as a bewildered and helpless stranger, but as a traveller who knows how to find his bearings in an unfamiliar country.
>
> . . . . . . . . . . . . . . . . . . .
>
> [Science education should] provide future generations not only with a general understanding of science as such, but, most of all, with the capacity to appreciate those aspects of science which affect the future of man--the impact of science on public affairs, on the fate of our own nation and of mankind as a whole. This means that science should be taught not as a separate body of technical facts, or an autonomous system of ideas, but in relation to other disciplines that traditionally mould the attitude of growing generations toward the society and the world they will live in: history, political science, sociology....

## Related Studies

Conant (1947) suggested the use of a historical approach as a means of developing an understanding in college students of the nature of scientific inquiry, of science as an enterprise, and of scientists as people. This suggestion resulted eventually in the development of the Harvard Case Histories of Experimental Science. However, no studies have been reported indicating the success of these cases.

Klopfer and Watson (1957) made an informal survey of high school science teachers to determine the extent to which historical materials were being used at the secondary level. The 35 replies to the survey questionnaire showed a wide diversity in the use of historical material; these range from telling anecdotes and stories and reading historical descriptions in textbooks to modified use of the Harvard Case Histories. The survey also revealed that teachers generally acknowledge the value of historical material in science teaching. Klopfer and Watson (1957) conclude:

> The inclusion of material from the history of science in education is not confined to college general education courses, for in secondary school also the use of historical material is far from being a rarity.

Klopfer and Watson introduced the case history approach to science instruction to the secondary school level by the development of the History of Science Cases for High School (HOSC) (1960). Six cases form the core of the HOSC; they are intended for use as separate units of instruction within existing courses in high school biology, chemistry, or physics.

Cooley and Klopfer (1963) devised an instrument to measure the change in student understanding of science after being instructed by the HOSC method. The Test of Understanding Science (TOUS) (1961) was used to measure the influence of HOSC on students in over 100 high schools throughout the United States. According to Klopfer and Cooley (1963) the purpose of the study was

> to evaluate the effectiveness of the HOSC Instruction Method in changing understanding of science and scientists.

The data analysis of the results of a relatively large and varied sample (2,808 biology, chemistry, and physics students in 108 schools) showed that the HOSC Instruction Method is definitely effective in increasing student understanding of science and scientists when used in biology, chemistry, and physics classes in high school. Klopfer and Cooley (1963) state:

> they [students] achieve significant gains in understanding of science and scientists with little or no concomitant loss of achievement in the usual content of high school science courses.

Carrier (1962) developed a unit on chemical change utilizing the case history approach. The material was designed to be taught to seventh grade students. Two experimental groups of 20 and 31 students received instruction via the experimental method but at different times during a six-week summer session. The investigator used an evaluation instrument composed of items selected from the TOUS test. The major findings were:

> 1. The results of the study indicated that the use of history of science material resulted in a significant increase on a "Test of Understanding Science."
> 2. An analysis of the test responses indicated that a general factor was responsible for the increase in achievement rather than any single specific factor.
> 3. Students who received HOSC instruction earlier in the course continued to improve in their understanding of science and scientists,....The students who received HOSC instruction during the latter two-week period did better than the other class during any two-week period. The students in the control group showed no significant change in their understanding of the three themes covered in the test.

Thomas (1967) developed a case, "The Earth's Crust," in the area of geology to be taught to subjects having a low interest or aptitude in science. In this study, the only teacher assistance offered was the reading guides that contained reading references recommended for the unit. This unit was taught to about 150 students in physical science classes who were compared with 175 students who were taught a text-centered unit. The problem of the study was:

> To compare achievement in the understanding of science, scientists, and the methods and aims of science between groups of students taught by two methods.

The investigator concluded that teaching via a case history approach was effective in increasing understanding of science and scientists.

Casteel and Yager (1968) report the development of a five-unit program interrelating science and culture. The Iowa Science and Culture Project (ISCP) had its genesis as an experimental high school class at the University of Iowa Experimental School in 1964. The program has been evaluated in terms of the specific goals of science and social studies education, as well as general education goals. Cossman (1968) has concluded that ISCP is successful in improving the students' understanding of science and scientists. He states:

> The outcome of this study indicates that it is possible to design and teach materials which bring about changes in the literacy of students with regard to science and simultaneously foster several important scientific attitudes.

Klopfer (1968) and others are developing a new physical science course which contains a major component of instructional materials that consider science and its cultural context. The junior-senior course--entitled "Matter, Energy, Radiation, and Man" (MERMAN)--was specifically designed to implement the social goals of science education. The course was first taught during the 1967-68 school year at the University High School of the University of Chicago. It is still in the development stage and has not been evaluated.

The only study of the socio-historical approach to science instruction was carried on by Boles (1968) who developed a teaching unit utilizing the opposing concepts of spontaneous generation and biogenesis. The unit was taught to three high school biology and one high school social science classes. The results of the study indicate that it is feasible to teach biology via a socio-historical approach utilizing the ideas of biogenesis and spontaneous generation with an emphasis on the social implications. As Boles states:

> The feasibility of teaching biology via a socio-historical approach utilizing the ideas of biogenesis and spontaneous generation with emphasis on the social implications of the two ideas is indicated for the following reasons:
>
> 1. Analysis of mean pretest and posttest scores indicates that classes in which students of average ability and above were enrolled exhibited a significant increase in subject matter knowledge related to biological concepts, nature of the scientific enterprise and the work of the scientists related to the biological concepts involved, and the social implications of the biological concepts involved.
>
> 2. There was no significant difference between the levels of performance demonstrated by classes in which eleventh- and twelfth-grade students were enrolled to study second year biology and the class in which tenth-grade students were enrolled to study social studies.

3. Students experiencing instruction utilizing the unit expressed a high level of interest in the reading material utilized as the basic text for the unit.

4. The majority of the students expressed the opinion that the reading material which formed the basis for the unit was not as difficult as most of the reading material in biology with which they were familiar.

## CHAPTER III. PROCEDURE

### Central Theme

The unit used in this study was based upon the central theme, the development of atomic energy and its social implications. This central theme was chosen as the basis for the selection of subject matter for the unit because Fuller (1952), Rabinowitch (1958), Dubarle (1960), and Seaborg (1966) indicate that it:

1. is of scientific and social importance;
2. has had a history of development that has been influenced by scientific attitudes and social conditions;
3. provides an opportunity to show how science and society interact;
4. provides an opportunity to show that the solution of one social, scientific, or technological problem can create new and often unforeseen implications for society, science, and technology;
5. provides an opportunity for the consideration of moral and ethical questions related to the pursuit of science; and
6. provides an opportunity to show that new developments in science have earlier and more fundamental backgrounds.

## Design of the Study

The study was divided into three phases:

1. Development - selection of concepts and the development of instructional materials;

2. Field Testing - selection of experimental groups and classroom instruction; and

3. Evaluation - evaluation and analysis of data.

### Development

#### Selection of Concepts

The selected concepts that were utilized in the development of the instructional materials were chosen during an extensive search that involved the study of library materials related to:

1. the history of science;
2. science and society;
3. atomic energy and its social, economic, political, and military implications;
4. atomic weapons and warfare;
5. the utilization of atomic energy;
6. the history of the atom bomb; and
7. the concept of the atom and its historical development.

Appendix E includes a bibliography of references from which the concepts were selected.

The selected concepts are divided into three categories:

a. concepts related to science and scientists;

b. concepts related to the interrelationships of science and society; and

c. concepts related to the atom and atomic energy.

## Concepts for the Unit:

## The Development of Atomic Energy and Its Social Implications

a. Concepts related to science and scientists.

Energy released when atomic nuclei undergo fission is being used at an increasing rate as a source of electrical power; it is the result of many years of dedicated work by many scientists and technologists.

The development of the procedures that led to the release of atomic energy is the result of the labors of scientists from many countries.

The scientist of today is no more intelligent or imaginative than his predecessor but he does have the advantage of a greater amount of scientific knowledge.

Some of the beliefs related to the nature of matter have been based upon direct observations from which incorrect conclusions have been made (an example is Thales' theory of water being "primary matter").

It is difficult to divide scientists into separate categories; their activities are interrelated and interdependent.

Science, considered as an organized social activity for describing and controlling the material world, had its historical roots in technical and spiritual traditions.

Although "scientist" is a modern term used to describe individuals who practice science, the practice of science dates back to antiquity.

Technological activities resulting in important inventions such as the telescope were the result of trial-and-error motivated by the desire to produce a specific product.

Scientists utilize many methods in their studies of nature; there is no one scientific method.

Early scientists employed the concept of supernatural power to explain many phenomena (such as the life of organisms) they did not understand.

Science is directed by reason and corrected through observations while magic is taught by mysterious initiations and is usually explained by myth. The Mesopotamians and Egyptians viewed illness as an evil spirit. The 'demon' theory of disease was the prevalent explanation of illness during these times.

Empirical science is based on direct and indirect observations. As time has passed the observations employed have moved from gross to precise.

The idea of fundamental substances in nature was formally stated by Thales whose philosophy included the belief that water was a fundamental substance in nature.

Empedocles introduced the concept that all matter was produced by the union of the four elements--water, air, earth, and fire--which were not themselves resolvable into simpler particles.

Leucippus and Democritus proposed that all matter consisted of eternally moving indestructible atoms, qualitatively alike but differing in size, shape, and mass.

Early Greek science was influenced by Plato's philosophy that ideas should be based on images created in the mind rather than on observations made with the senses.

Plato and Aristotle abandoned the effort to account for physical forces exclusively and the great influence they had on later thought was detrimental rather than stimulating to the advance of physical science.

Aristotle, whose authoritarian viewpoint of the nature of matter controlled thinking on this subject for about 2000 years, believed that matter is continuous and infinitely divisible.

Aristotle (who was once a tutor to Alexander the Great) led applied scientists (alchemists) to believe that they could change base metal into gold.

Alchemy, derived from Greek Alexandrian science and cultivated with great secrecy, encompassed cosmology, mysticism, and astrology.

Arab scientists, such as Al-Kindi, were patronized by the Arab rulers who wanted to accumulate all scientific knowledge in the Islamic empire.

The scientists employed by Arab rulers (about A.D. 900) made great contributions to science through their translations and summaries of the works of the Greek natural philosophers.

During Medieval times, many scientists (such as Roger Bacon, St. Thomas Acquinas, and Albertus Magnus) contributed little new insight into the study of matter because they were members of religious orders that were advocates of Aristotle's ideas.

Most scientists prior to the 17th Century developed generalizations from mental images and applied them to natural phenomena by deduction.

The scientist of the Middle Ages was usually a member of a religious order and or a practicing or court physician. They had some free time during which they practiced science.

Galileo, the beneficiary of wealthy patrons, presented ideas that cast doubt on Aristotle's works as the final authority in science.

Until the 17th Century scientific and social thought was dominated by the ideas of the Greeks. For example, the Greeks believed that everything in the universe was absolute and unchanging.

Francis Bacon, who served as Lord Keeper and Lord Chancellor under James I. advocated experimentation in science and believed that observation and tabulation were important aspects of scientific investigations.

During the 17th Century, the accurate accumulation of data resulted in the formulation of theoretical models consistent with observations; the observations were not distorted to fit "self-evident truth."

Dalton proposed an atomic theory to explain regularities that were found to exist in the interactions of matter.

Unexpected but fortunate discoveries, such as Becquerel's discovery of radioactivity, often play an important part in scientific investigations.

The most crucial test of experimental findings is whether or not they can be repeated under comparable conditions by other scientists.

A handful of gifted scientists, mostly refugees of Hitler and Mussolini, were responsible for the primary discoveries leading to the harnessing of atomic energy.

Since the start of the "Manhattan Project" the influence of scientists on government policy has increased; in addition, there has been a proliferation of government supported group research, i.e., physicists, chemists, biologists, mathematicians, and engineers--all working on one research project.

The findings of research scientists should be made available to other research scientists.

b. Concepts related to the interrelationships of science and society.

The relationships between scientists and society have varied throughout history. The early scientists or natural philosophers had to be wealthy or had to rely on the patronage of wealthy benefactors. Modern scientists have become increasingly dependent upon national governments for financial support.

The products of science and technology have been important factors in the social and economic development of many countries.

Concepts of the atom have changed with time; atoms have been perceived differently by different societies.

Social involvement of science varies with time and locality. National and international political situations have encouraged the use of scientists for governmental service.

The first civilizations, such as Mespotamia and Egypt, developed along rivers that supplied sufficient fertile land to support large communities. These communities were restricted to these fertile river valleys.

The flooding cycles of the Nile and the Tigris-Euphrates had an influence on the stability of the society and its scientific practices. The predictable Nile made the future seem certain; the science of Egypt was primarily concerned with practical endeavors such as medicine and the application of mathematics to surveying. The unpredictable Tigris-Euphrates made the future seem uncertain; the Mesopotamian scientist resorted to astrology and the examination of sacrificial livers in an attempt to bring order to their chaotic life situation.

Early Mesopotamian societies (about 2500 B.C.) delegated the development of calendars, which were used to make predictions about planting times for crops and to determine the proper times to glorify their gods, to their priestly scribes. The Zodiac and the naming of the days of the week originated with the work of these observers of phenomena.

Theoretical science could grow in Greece because of Greece's simple political structure at the time, the freedom from superstitious control found in other early civilizations, and commercial sea travel which aided in the gathering of ideas.

Science at the time of the ancient Greeks was primarily an intellectual activity of the leisure class; one reason for the absence of experimentation during this time was the dislike for manual labor by the leisure class.

The Romans failed to carry on the Greek scientific revolution because their main interest in science was technological and they lacked the freedom of the Greeks.

The invention of printing by Coster and Gutenberg had tremendous influence on the development of science since the dissemination of scientific information was made easier.

European scientists during the Middle Ages were inspired to utilize scientific inquiry for religious and economic purposes.

The academy, lyceum, university, and scientific society were centers of scientific activity with the university leading during the late Middle Ages.

Society has at times been intolerant of science and the scientist; an example of intolerance for certain scientific ideas by established authority was the 17th Century condemnation of Galileo for defending the heliocentric concept of the universe.

Empirical science requires the support of financial benefactors; it first flourished in Italy, France, England, and in other parts of western Europe where a strong economic structure existed.

Science has been developing for centuries but it was not until the middle of the 19th Century that scientific developments began to have practical and therefore economic consequences for society. Synthetic fertilizers, dyes, and drugs are products of scientific developments that resulted in the expansion of industry and the consumer market.

France was the first country to recognize science as a national asset but Germany was the first country to develop industrial and political strength by institutionalizing science at the national level.

In this century many countries have realized the significance of science and, as a consequence, have encouraged the pursuit of science.

Political instability and intolerance of some governments has resulted in scientists migrating to other countries; central Europe during the pre-World War II years witnessed such a period of instability and intolerance.

German science began to decline when the Nazis gained control of Germany, largely because the Nazi philosophy opposed many scientific ideals.

The principal goal for developing nuclear energy by the United States during World War II was to deter Hitler from using it as a weapon.

Prior to 1939 no regular program for U.S. government support of theoretical science existed; university scientists did not have representation among government officials.

Before World War II research in new fields of science such as nuclear research had not been recognized by the U.S. government as a significant national resource; basic research was not given governmental support.

On December 6, 1941 the United States started the Manhattan Project. This day marked a change in attitude among U.S. scientists and politicians; gone was the hesitation of spending public money on the theories of a few men.

"Manhattan Project," the code name for the atom bomb project, was an integrated scientific and technological endeavor under the direction of the U.S. Army Engineers.

Active participation of scientists in United States' politics is primarily due to the development of atomic energy; decisions in matters of atomic energy are intimately involved with science and technology.

A sympathetic government policy toward science is important in developing and maintaining scientific activities.

Government supported science is effective in meeting the internal needs of a country and, in addition, science is of importance in establishing the international position of a country.

Countries with a limited development of their natural resources could greatly benefit from the services of basic science and technology. Countries such as India and Brazil could benefit from a well-established scientific community.

The diminishing gap between scientific discovery and technological application necessitates a high degree of social responsibility on the part of scientists to consider possible adverse social consequences of scientific investigations.

Social techniques are needed to insure that decisions made by politicians, with the advice of a few scientific experts, concerning scientific research will truly reflect the needs of society.

The first U.N. Geneva Conference, "Atoms for Peace," was a historic event since it was the first time that high government officials of various governments sat together with technical and scientific experts from various countries.

The "Atoms for Peace" program gave impetus to industrial applications and controlled atomic assistance to developing nations which the International Atomic Energy Agency administers.

Many discoveries and developments of science have had economic, sociological, and philosophical implications. Atomic energy utilization has resulted in the need for: more complicated equipment, new metals, and greater machine precision; specially trained technicians to handle sophisticated equipment; the safe disposal of radioactive waste materials harmful to organisms; and world-wide cooperation for its use.

c. Concepts related to the atom and atomic energy.

The four elements, according to Aristotle, are properties or qualities rather than substances; one element can be changed into another by overcoming one property of its opposite.

The "primary elements" of the early Greeks are known today to be compounds and mixtures.

Radioactivity, a property exhibited by certain chemical elements, is observable when atomic nuclei undergo change to more stable arrangements; this change is independent of any external influence.

Rutherford proposed that each atom is made up of a central nucleus that is positively charged and is surrounded by electrons.

The neutron, discovered by Chadwick, was used as a projectile by Fermi and co-workers to bombard atoms; the ultimate result of this experimentation was the discovery of nuclear fission.

Nuclear reactions differ from ordinary chemical reactions because the nucleus undergoes change; heavy nuclei split into lighter nuclei when bombarded by particles such as neutrons.

The explosion of an atomic bomb is an uncontrolled chain reaction that produces energy in the form of thermal (heat) and gamma radiation. Rapidly moving nuclear fragments account for the remaining energy.

When the nucleus of an atom of plutonium 239 or uranium 235 is penetrated by a neutron, the following events occur: (1) the nucleus splits into two large fragments; (2) neutrons are emitted; and (3) energy is released.

A self-sustaining chain reaction (nuclear fission) occurs when the number of neutrons released by nuclei during fission equals or exceeds the number of neutrons absorbed by nuclei.

Nuclei of isotopes have the same number of protons but different numbers of neutrons; both uranium 235 and uranium 238 have 92 protons but they have 143 and 146 neutrons respectively.

An assemblage of fissionable material and a moderator (such as graphite or heavy water) form what is known as an atomic pile or an atomic reactor.

The minimum amount of fissionable material necessary to sustain a chain reaction is known as the critical assemblage or critical mass.

Atomic energy, one of the biggest scientific, technological, and business enterprises of the United States, developed from discoveries in basic research.

The radioactive decay of atoms is accompanied by the release of heat; scientists realized that radioactive materials could be a source of heat energy that could be converted into power.

The Atomic Energy Commission (AEC) controls all aspects of atomic energy utilization in the United States; it is a controlling agency free of profit motive. This action was preferred over the release of the control of atomic energy utilization to the military or private enterprise.

Peaceful uses of atomic energy cannot be separated from the technology that is necessary for the development of atomic weapons; therefore, concern for control of atomic energy for destructive purposes has preoccupied our attention at the expense of peaceful applications.

A nuclear chain reaction can be very rapid or it can be slowed down so that the production of energy can be controlled.

One of the unique attractions of nuclear power is its relative independence of geography; atomic energy may make the building of modern cities in regions remote from existing sources of power possible.

Nuclear power plants cost more to build than regular power plants because they must include many safety devices. They are less popular than regular power plants.

Nuclear radiation is a hazard to living organisms. One of the greatest problems in research and the industrial production of radioactive materials is not the danger of an explosion, but the protection of people from lethal doses of radiation. Radiation cannot be detected by any of the natural senses.

In the process of radioactive decay atoms release energy in the form of heat and radiation that can be transformed into a variety of scientific, medical, and industrial uses.

Radioactivity cannot be neutralized or destroyed by any process; therefore, the international community is faced with a problem of the safe disposal of large quantities of radioactive waste materials.

Nuclear fusion is a reaction in which nuclei of lighter elements are combined to form a nucleus of a heavier element.

When a charged particle penetrates the nucleus of an atom the result is the formation of a different element.

Ionizing radiation can cause mutations in living organisms other than natural mutations.

Nuclear changes may be brought about by penetrating the atomic nucleus with particles or radiation.

The chemical properties of an ingested radioisotope determines where the isotope will be deposited in the body.

Radioisotopes produced during a nuclear fission reaction have half-lives that vary widely.

A useful reactor control rod absorbs neutrons and causes the rate of nuclear fission to decrease.

Mass that is apparently lost when a nucleus splits appears as energy.

The half-life of a radioactive element is the amount of time it takes half of the radioactive atoms to undergo radioactive decay.

## Development of Instructional Materials

The instructional materials for the unit, The Development of Atomic Energy and Its Social Implications, include:

1. a narrative or text for the student, consisting of 12 chapters divided into three main sections;

2. a teacher's guide organized by chapters that includes teaching suggestions;

3. a set of 2x2 slides with an accompanying narrative; and

4. four motion picture films from the Atomic Energy Commission.

The narrative for the student, written by the investigator, is concerned with the historical development of atomic energy and its social implications, and in addition, the interrelationships of scientists and society during selected periods of history (Appendix E). These materials were written with a readability level, as determined by the Fog Index for Predicting Readability (Gunning, 1952), appropriate for students in high school (10th to 12th grade level). The sections, chapters, and general topics of each chapter are:

Section I. The Development of Faith in Science

Chapter I. An Introduction to Nuclear Energy, Scientists, and Society; 11 pages.

Chapter II. The Beginnings of Science - Prehistoric, Egyptian, and Mesopotamian Science; 20 pages.

Chapter III. Greek Science - The Speculation of the Greeks about the Nature of Matter; 24 pages.

Chapter IV. The Eclipse of Science - Roman, Arabian, and Early Christian Science; 19 pages.

Chapter V. Rebirth of Science - The University, Scientific Societies, and Some Leaders of 17th Century Science; 26 pages.

Chapter VI. 18th, 19th, and 20th Century Science - The Change of Scientists from Amateurs to Professionals; 32 pages.

Section II. Excess Faith in Science by Society (Scientism)

Chapter VII. From Radioactivity to the Neutron - Contributions of Roentgen, Becquerel, the Curies, and Rutherford; 33 pages.

Chapter VIII. U.S. Science and Politics Merge - Political Activities in Europe Prior to World War II and the Discovery of Nuclear Fission; 26 pages.

Chapter IX. From the Laboratory to Alamogordo - The Manhattan Project; 28 pages.

Chapter X. Science Wins the War - The German Atom Bomb Project and the Decision to Use the Atom Bomb; 28 pages.

Section III. The Changing Image of Science From a National to an International Force

Chapter XI. Atomic Energy and Society - The International and Domestic Problems Associated with Atomic Energy and the Peaceful Uses of Atomic Energy; 26 pages.

Chapter XII. Nuclear Energy, Science, and the Future - Some of the Risks Associated with Nuclear Energy and the Role of Scientists in Society; 16 pages.

The narrative includes quotations of scientists, historians of science, and political scientists to give the student a more personal rapport with the people and their activities.

Photographic reproductions in the form of 2x2 slides of maps, time charts, pictures, sketches, etc. were obtained from various sources, assembled, and used to describe and call attention to important ideas, places, and people (Appendix I). The narration for the slides, which was written for the teacher, was used to integrate the slides with the textual material of the unit (See Appendix H).

The teacher's guide was developed to provide for a uniform and consistent presentation of the unit. The guide, organized by chapters, lists ideas to be considered and gives suggestions for the use of the student text, slide narrative, slides, and movies (See Appendix F).

Four 16mm motion picture films pertinent to the unit were obtained from the Atomic Energy Commission and shown at appropriate times during the unit. The films, ranging in length from about 15 to 30 minutes, are described in Appendix G.

## Field Testing

The field testing phase included 19 days of instruction and evaluation. The instruction--conducted by this investigator--was carried out over a period of 14 days; an additional five days were utilized for the administration of the evaluation instrument, an interest survey, and the student questionnaire.

## Selection of the Population

The selection of the population to serve in the testing of the materials was based upon the availability of schools, and the willingness of teachers to cooperate with the experimentation. The original design included a provision for an experimental comparison of science and social science classes from the same population but the desired arrangement could not be found. Therefore, the investigator utilized science and social science classes available from two different populations which precluded a statistical comparison; however, the results of the two groups of classes are presented in this study.

## Description of Selected Groups

The experimentation was carried out in two schools in two different communities. The description of the two populations follows.

School A is located in a south central Wisconsin industrial community with an estimated 1970 population of 55,000. The school has a total enrollment of about 1300 Eleventh- and Twelfth-Grade students. The classes used in the study were four Twelfth-Grade heterogeneously grouped American Problems classes. The heterogeneity in terms of ability of these 107 students is indicated by the IQ range (72-147). The computed mean IQ for the total group is 104.86 with a standard deviation of 13.33. To facilitate the description of the population the mean number of years of science and mean number of years of social science completed by the students are listed in Table 2. The students, on the average, have completed 2.58 years of science and 3.25 years of social science during their first three years of high school.

School B is located in a south central Wisconsin semi-industrial community with an estimated 1970 population of 50,000. The school has a total enrollment of about 1250 Tenth-, Eleventh-, and Twelfth-Grade students. The classes participating in the study were four homogeneously grouped classes consisting of 9 Tenth-Grade, 62 Eleventh-Grade, and 5 Twelfth-Grade students studying chemistry.

The students in the chemistry (1) and chemistry (4) classes were classified by the school as above average; whereas, those in the chemistry (2) and chemistry (3) classes were classified as average. The IQ range for the four classes is 100 to 148 and the mean IQ is 121.68 with a standard deviation of 11.79 (Table 3). The students in School B have taken more courses in science than in social science. The mean number of years of science and social science are 2.95 and 2.16 years respectively (Table 4).

TABLE 1

SCHOOL A - AMERICAN PROBLEMS CLASSES

THE ABILITY OF THE STUDENTS AS INDICATED BY IQ.

| Class | (1) | (2) | (3) | (4) | Total Group |
|---|---|---|---|---|---|
| IQ Range | 89-131 | 84-137 | 72-147 | 89-136 | 72-147 |
| Mean IQ | 105.46 | 104.44 | 102.17 | 107.77 | 104.86 |
| Standard Deviation | 11.76 | 11.08 | 15.54 | 14.11 | 13.33 |
| Number of Students | 26 | 25 | 30 | 26 | 107 |

TABLE 2

SCHOOL A - AMERICAN PROBLEMS CLASSES

MEAN NUMBER OF YEARS OF SCIENCE AND SOCIAL SCIENCE COMPLETED BY THE STUDENTS.

| Classes | Mean Years | |
|---|---|---|
| | Science | Social Science |
| (1) | 2.34 | 3.16 |
| (2) | 2.72 | 3.32 |
| (3) | 2.51 | 2.93 |
| (4) | 2.68 | 3.25 |
| Group Means | 2.58 | 3.25 |

TABLE 3

SCHOOL B - CHEMISTRY CLASSES

THE ABILITY OF THE STUDENTS AS INDICATED BY IQ.

| Class | (1) | (2) | (3) | (4) | Total Group |
|---|---|---|---|---|---|
| IQ Range | 114-145 | 100-133 | 105-127 | 110-148 | 100-148 |
| Mean IQ | 126.42 | 113.05 | 115.37 | 130.43 | 121.68 |
| Standard Deviation | 8.82 | 10.42 | 7.65 | 9.82 | 11.79 |
| Number of Students | 19 | 20 | 16 | 21 | 76 |

TABLE 4

SCHOOL B - CHEMISTRY CLASSES

MEAN NUMBER OF YEARS OF SCIENCE AND SOCIAL SCIENCE COMPLETED BY THE STUDENTS.

| Classes | Mean Years | |
|---|---|---|
| | Science | Social Science |
| (1) | 2.90 | 1.85 |
| (2) | 3.00 | 2.10 |
| (3) | 3.00 | 2.40 |
| (4) | 2.90 | 2.30 |
| Group Means | 2.95 | 2.16 |

## Evaluation

### Evaluation Instrument

A 90-item five-alternative multiple choice test was developed utilizing the selected concepts of the unit. The instrument, divided into three 30-item subtests, included items that were randomly selected from a pool of items written for the three categories of concepts (one item for each concept). The three subtests were concerned with concepts related to

a. science and scientists,

b. the interrelationships of science and society, and

c. the atom and atomic energy.

The items in each subtest were randomly separated into two 15-item subgroups for use in the two parts of the test.

The evaluation instrument, divided into two 45-item parts, was administered to the students as a pretest and posttest. The pretest administration was completed on two consecutive days before and the posttest on two consecutive days following the presentation of the instructional materials.

### Student Questionnaire

The student questionnaire was a composite of general information and opinion questions (Appendix D). The general information questions were concerned with

1. the student's academic background in science and social science,

2. the average and maximum time he used to read the chapters of the text, and

3. the extent to which he read each chapter of the text.

In the opinion section of the questionnaire the student was asked:

1. to compare the difficulty of the text to other science and social science reading materials;

2. to compare his interest in the material of the unit to other science and social science reading materials;

3. to evaluate the change in his interest in science;

4. to evaluate the change in his understanding of science and scientists, science and society, and atoms and atomic energy;

5. to identify the most and least interesting chapters; and

6. to identify a method of instruction that would help to improve his understanding of the unit.

## Analysis of Data

The data collected during this study were analyzed as follows:

1. To determine the magnitude of the gains in achievement in subject matter knowledge related to

a. science and scientists,

b. the interrelationships of science and society, and

c. the atom and atomic energy as indicated by differences between pretest and posttest class mean scores.

2. To determine the significance of the gains in achievement using the <u>t-test for paired means</u> (mean scores) (Hays, 1963) with the pretest and posttest scores of a class used as a "pair" and the classes as independent subjects with N=4 experimental classes. The null hypothesis in this analysis is:

$H_o$: Classes receiving instruction via the socio-historical approach did not perform significantly better on the posttest than on the pretest as indicated by a statistical comparison of pretest and posttest mean scores ($\alpha = .001$).

The class mean gain ($D_i$) for the total test and subtests were obtained using

$$D_i = (\overline{X}_{i1} - \overline{X}_{i2})$$

where $\overline{X}_{i1}$ is the posttest mean score of class (i) and $X_{i2}$

is the pretest mean score of class (i).

The group mean gain ($M_D$) and Variance ($S_D^2$) for the total test and subtests were obtained using

$$M_D = \frac{\sum_i D_i}{N}$$

and

$$S_D^2 = \frac{\Sigma (D_i - M_D)^2}{N - 1}$$

where N is the number of class gain scores or number of pairs of pretest and posttest class mean scores (4) and N-1 is the number of degrees of freedom (3).

The group mean gain scores for the total test and subtests were tested for significance by using the *t*-test for matched pairs.

$$t = \frac{M_D - E(M_D)}{\text{est. } \sigma M_D}$$

where

$$E(M_D) = \mu_1 - \mu_2, \text{ or } 0$$

and

$$\text{est. } \sigma M_D = \frac{S_D}{\sqrt{N}}$$

Since classes were not available for control and the unit was taught by the investigator, a conservative criterion of $\alpha = .001$ was adopted for the experimental classes to maximize the likelihood that any achievement gain scores that might occur within the experimental classes were not attributable to chance.

3. The relationships between the individual student IQ and individual gain scores on

a. the total test,

b. the science and scientist subtest,

c. the science and society subtest, and

d. the atomic energy subtest were determined by calculating the correlation coefficient (r) between the individual IQ and individual gain scores.

4. The relative independence of the several subtests making up the evaluation instrument was analyzed using correlational analyses of individual gain scores.

5. The student responses to the

a. level of difficulty,

b. level of interest,

c. change in the students' interest, and

d. change in the students' understanding of the subject matter are presented in both numerical and percentage tabulations.

6. Internal consistency reliabilities (pretest and

posttest) for the total and the subtests were determined by utilizing the <u>General Item and Test Analysis Program</u> (Baker, 1969). This program uses the Hoyt Analysis of Variance (ANOVA) to compute the internal consistency reliability. Appendices A and B have the item analysis and reliabilities for Schools A and B, respectively.

## CHAPTER IV. RESULTS

The results of the analyses of data used in this study to determine the feasibility of teaching science via a socio-historical approach are presented for the classes of School A (American Problems Classes) and School B (Chemistry Classes) in terms of:

1. characteristics of the evaluation instrument,

   a. reliabilities of the total test and subtests, and

   b. intercorrelations between subtest scores;

2. total test and three subtest mean gain scores by class and group;

3. student responses to the questionnaire concerning their interest in the instructional materials;

4. student responses to the questionnaire concerning changes in their understanding of

   a. science and scientists,

   b. science-society interrelationships, and

   c. the atom and atomic energy;

5. student responses to the questionnaire concerning

   a. the time devoted to reading the instructional material, and

   b. the difficulty of and interest in the unit when compared to other science and social science instructional materials; and

6. correlations between student test gains and IQ.

## 1. Characteristics of the Evaluation Instrument

### a. Reliabilities of the Total Test and Subtests

The posttest internal consistency reliabilities for the total test and subtests used in this study--determined by the Generalized Item and Test Analysis Program--are above the levels generally acceptable for group analysis (Table 5). The variations between the reliabilities for the two schools is probably a reflection of the differences in homogeneity of the two school populations used in the study rather than an instability of the evaluation instrument.

### b. Intercorrelations Between Subtest Scores

It is noted in Table 6 for School A and Table 7 for School B that the coefficients of correlation are low, indicating that the three subtests are relatively independent of each other. Since the subtests were developed to measure achievement in terms of gains in knowledge of a) science and scientists, b) the science-society interrelationships, and c) the atom and atomic energy, the low coefficients of correlation indicate that the measurement of knowledge of one category (a, b, or c) is essentially independent of the other two.

## 2. Class and Group Mean Gain Scores

It is noted from Tables 8, 9, 10 and 11 for School A and Tables 12, 13, 14, and 15 for School B that the achievement gains, as indicated by total test and individual subtest scores of the classes in both schools are positive, generally uniform within schools, and significant at the .001 level; however, the gains in School B are much greater. This superiority of the Chemistry Classes over the American Problems Classes may be accounted for by the fact that the students in the Chemistry Classes were in effect a select group; the chemistry course is considered difficult in the school hence only well-motivated students enroll.

TABLE 5

SCHOOL A - AMERICAN PROBLEMS CLASSES
AND
SCHOOL B - CHEMISTRY CLASSES

INTERNAL CONSISTENCY RELIABILITIES
OF THE TOTAL TEST AND SUBTESTS

(POSTTEST)

| School | Subtest a (Science & Scientists) | Subtest b (Science & Society) | Subtest c (Atoms & Atomic Energy) | Total Test |
|---|---|---|---|---|
| A | .730 | .746 | .818 | .903 |
| B | .600 | .502 | .559 | .780 |

TABLE 6

SCHOOL A - AMERICAN PROBLEMS CLASSES

INTERCORRELATIONS BETWEEN SUBTESTS AND TOTAL TEST

| | Subtest a (Science & Scientists) | Subtest b (Science & Society) | Subtest c (Atoms & Atomic Energy) | Total Test |
|---|---|---|---|---|
| Subtest a | 1.000 | | | |
| Subtest b | .253 | 1.000 | | |
| Subtest c | .184 | .269 | 1.000 | |
| Total Test | .681 | .716 | .703 | 1.000 |

TABLE 7

SCHOOL B - CHEMISTRY CLASSES

INTERCORRELATIONS BETWEEN SUBTESTS AND TOTAL TEST

| | Subtest a (Science & Scientists) | Subtest b (Science & Society) | Subtest c (Atoms & Atomic Energy) | Total Test |
|---|---|---|---|---|
| Subtest a | 1.000 | | | |
| Subtest b | -.018 | 1.000 | | |
| Subtest c | -.028 | .105 | 1.000 | |
| Total Test | .593 | .565 | .603 | 1.000 |

TABLE 8

SCHOOL A - AMERICAN PROBLEMS CLASSES

PRETEST AND POSTTEST MEAN SCORES AND MEAN GAINS BY CLASS AND GROUP

(TOTAL TEST)

| Class | Pretest $\bar{X}$ | Posttest $\bar{X}$ | Gain |
|---|---|---|---|
| (1) | 33.50 | 48.26 | +14.76 |
| (2) | 36.92 | 50.36 | +13.44 |
| (3) | 37.40 | 49.53 | +12.13 |
| (4) | 34.84 | 47.92 | +13.07 |
| Group Means | 35.72 | 49.02 | +13.30 |

Computed value of _t_ with 3 df: 24.20

Critical value of _t_ with 3 df: 10.21 ($\alpha$=.001,one-tailed test)

TABLE 9

SCHOOL A - AMERICAN PROBLEMS CLASSES

PRETEST AND POSTTEST MEAN SCORES AND MEAN GAINS BY CLASS AND GROUP

(SUBTEST a: CONCEPTS RELATED TO SCIENCE AND SCIENTISTS)

| Class | Pretest $\bar{X}$ | Posttest $\bar{X}$ | Gain |
|---|---|---|---|
| (1) | 11.61 | 16.23 | +4.61 |
| (2) | 13.08 | 16.76 | +3.68 |
| (3) | 13.20 | 16.96 | +3.76 |
| (4) | 12.92 | 16.57 | +3.65 |
| Group Means | 12.72 | 16.64 | +3.92 |

Computed value of _t_ with 3 df: 17.00

Critical value of _t_ with 3 df: 10.21 ($\alpha$=.001,one-tailed test)

TABLE 10

SCHOOL A - AMERICAN PROBLEMS CLASSES

PRETEST AND POSTTEST MEAN SCORES AND MEAN GAINS BY CLASS AND GROUP

(SUBTEST b: CONCEPTS RELATED TO THE INTERRELATIONSHIPS OF SCIENCE AND SOCIETY)

| Class | Pretest $\bar{X}$ | Posttest $\bar{X}$ | Gain |
|---|---|---|---|
| (1) | 9.19 | 14.65 | +5.46 |
| (2) | 9.84 | 16.76 | +4.80 |
| (3) | 11.13 | 15.10 | +3.96 |
| (4) | 9.57 | 13.80 | +4.23 |
| Group Means | 9.98 | 14.57 | +4.59 |

Computed value of *t* with 3 df: 13.72

Critical value ot *t* with 3 df: 10.21 ($\alpha$=.001,one-tailed test)

TABLE 11

SCHOOL A - AMERICAN PROBLEMS CLASSES

PRETEST AND POSTTEST MEAN SCORES AND MEAN GAINS BY CLASS AND GROUP

(SUBTEST c: CONCEPTS RELATED TO THE ATOM AND ATOMIC ENERGY)

| Class | Pretest $\bar{X}$ | Posttest $\bar{X}$ | Gain |
|---|---|---|---|
| (1) | 12.69 | 17.38 | +4.69 |
| (2) | 14.00 | 18.96 | +4.96 |
| (3) | 13.06 | 17.46 | +4.40 |
| (4) | 12.34 | 17.53 | +5.19 |
| Group Means | 13.01 | 17.81 | +4.79 |

Computed value of *t* with 3 df: 27.80

Critical value of *t* with 3 df: 10.21 ($\alpha$=.001,one-tailed test)

TABLE 12

SCHOOL B - CHEMISTRY CLASSES

PRETEST AND POSTTEST MEAN SCORES AND MEAN GAINS
BY CLASS AND GROUP

(TOTAL TEST)

| Class | Pretest $\overline{X}$ | Posttest $\overline{X}$ | Gain |
|---|---|---|---|
| (1) | 47.21 | 69.21 | +22.00 |
| (2) | 37.85 | 61.05 | +23.20 |
| (3) | 37.00 | 58.50 | +21.50 |
| (4) | 47.19 | 68.76 | +21.57 |
| Group Means | 42.59 | 64.68 | +22.09 |

Computed value of *t* with 3 df: 55.30

Critical value of *t* with 3 df: 10.21 ($\alpha$=.001, one-tailed test)

TABLE 13

SCHOOL B - CHEMISTRY CLASSES

PRETEST AND POSTTEST MEAN SCORES AND MEAN GAINS
BY CLASS AND GROUP

(SUBTEST a: CONCEPTS RELATED TO SCIENCE AND SCIENTISTS)

| Class | Pretest $\overline{X}$ | Posttest $\overline{X}$ | Gain |
|---|---|---|---|
| (1) | 16.52 | 23.52 | +7.00 |
| (2) | 13.70 | 20.10 | +6.40 |
| (3) | 14.31 | 19.81 | +5.50 |
| (4) | 16.76 | 23.33 | +6.57 |
| Group Means | 15.38 | 21.78 | +6.40 |

Computed value of *t* with 3 df: 17.30

Critical value of *t* with 3 df: 10.21 ($\alpha$=.001, one-tailed test)

TABLE 14

SCHOOL B - CHEMISTRY CLASSES

PRETEST AND POSTTEST MEAN SCORES AND MEAN GAINS BY CLASS AND GROUP

(SUBTEST b: CONCEPTS RELATED TO THE INTERRELATIONSHIPS OF SCIENCE AND SOCIETY)

| Class | Pretest $\bar{X}$ | Posttest $\bar{X}$ | Gain |
|---|---|---|---|
| (1) | 14.57 | 21.47 | +6.90 |
| (2) | 10.95 | 19.70 | +8.75 |
| (3) | 10.31 | 18.75 | +8.43 |
| (4) | 14.09 | 21.81 | +7.71 |
| Group Means | 12.59 | 20.56 | +7.93 |

Computed value of *t* with 3 df: 19.30

Critical value of *t* with 3 df: 10.21 ($\alpha$ =.001, one-tailed test)

TABLE 15

SCHOOL B - CHEMISTRY CLASSES

PRETEST AND POSTTEST MEAN SCORES AND MEAN GAINS BY CLASS AND GROUP

(SUBTEST c: CONCEPTS RELATED TO THE ATOM AND ATOMIC ENERGY)

| Class | Pretest $\bar{X}$ | Posttest $\bar{X}$ | Gain |
|---|---|---|---|
| (1) | 16.10 | 24.21 | +8.10 |
| (2) | 13.20 | 21.25 | +8.05 |
| (3) | 12.37 | 19.93 | +7.56 |
| (4) | 16.33 | 23.61 | +7.28 |
| Group Means | 14.61 | 22.36 | +7.75 |

Computed value of *t* with 3 df: 39.00

Critical value of *t* with 3 df: 10.21 ($\alpha$=.001, one-tailed test)

3. Student Interest in the Instructional Method

When asked what effect the unit had on their interest in science, 39% of the students of School A reported an increase and only one student (1%) reported a decrease (Table 16). In addition, 66 or 61% of the students expressed the opinion that they would have read more about science and its relation to society if they had had more time (Table 17). The report from School B indicated that 87% of the students experienced an increase in interest in science (Table 18) and 67% of these students reported that they would have read more about the science-society relationship if they had had more time (Table 19).

In both schools the subject matter that was given a high rating in terms of interest was that concerned with the activities of people--scientists, politicians, and military men--and that given a low rating was related to the history of empires and nations. It is noted from Tables 20 and 21 that Chapters VII, IX, and X were rated by the students of both schools as most interesting and Chapter VII (the activities leading to the development of the atom bomb) by School B as most interesting. The chapters rated as least interesting by both groups were I, II, IV, V, and VIII. Group A also rated Chapter III as least interesting.

Examinations of Tables 22 and 23 reveal a lack of agreement among the two groups of students relative to "who would benefit from this approach;" however, they did agree that a population exists. Of interest is the fact that 44% of the students from the American Problems Classes and only 9% of the students in Chemistry Classes expressed the opinion that the course should be for students interested in a career in science. The students from the Chemistry Classes seemed to generally agree that all students would benefit from this kind of instruction (Table 23).

A similar difference of opinion is noted when responses to the question, "Would you be interested in taking a course utilizing the socio-historical approach?" are tablulated, Tables 24 and 25; 91% of the students in Chemistry Classes and only 51% of the students in American Problems Classes indicate that they would enroll in the course if it were available.

TABLE 16

SCHOOL A - AMERICAN PROBLEMS CLASSES

STUDENT RESPONSES TO:
"WHAT EFFECT HAS THIS UNIT HAD ON YOUR INTEREST IN SCIENCE?"

| Class | Number and Percent * | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | Total |
| Increased Interest Greatly | 1 (04) | 0 (--) | 0 (--) | 0 (--) | 1 (01) |
| Increased Interest Somewhat | 4 (15) | 10 (40) | 10 (33) | 17 (66) | 41 (38) |
| No Change | 21 (81) | 15 (60) | 19 (63) | 9 (34) | 64 (59) |
| Decreased Interest Somewhat | 0 (--) | 0 (--) | 1 (03) | 0 (--) | 1 (01) |
| Decreased Interest Greatly | 0 (--) | 0 (--) | 0 (--) | 0 (--) | 0 (--) |
| Total | 26 (99) | 25(100) | 30 (99) | 26(100) | 107 (99) |

TABLE 17

SCHOOL A - AMERICAN PROBLEMS CLASSES

STUDENT RESPONSES TO:
"IF YOU HAD MORE TIME WOULD YOU HAVE READ MORE ABOUT SCIENCE AND ITS RELATION TO SOCIETY?"

| Class | Number and Percent* | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | Total |
| Yes | 12 (46) | 15 (60) | 22 (73) | 16 (62) | 66 (61) |
| No | 14 (54) | 10 (40) | 8 (27) | 10 (38) | 41 (39) |
| Total | 26(100) | 25(100) | 30(100) | 26(100) | 107(100) |

*Percentages are in parentheses.

TABLE 18

SCHOOL B - CHEMISTRY CLASSES

STUDENT RESPONSES TO:
"WHAT EFFECT HAS THIS UNIT HAD ON YOUR INTEREST IN SCIENCE?"

| Class | Number and Percent* | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | Total |
| Increased Interest Greatly | 3 (16) | 3 (15) | 3 (19) | 1 (05) | 10 (13) |
| Increased Interest Somewhat | 15 (79) | 15 (75) | 11 (69) | 16 (75) | 56 (74) |
| No Change | 1 (05) | 2 (10) | 2 (12) | 5 (20) | 10 (13) |
| Decreased Interest Somewhat | 0 (--) | 0 (--) | 0 (--) | 0 (--) | 0 (--) |
| Decreased Interest Greatly | 0 (--) | 0 (--) | 0 (--) | 0 (--) | 0 (--) |
| Total | 19(100) | 20(100) | 16(100) | 21(100) | 76(100) |

TABLE 19

SCHOOL B - CHEMISTRY CLASSES

STUDENT RESPONSES TO:
"IF YOU HAD MORE TIME WOULD YOU HAVE READ MORE ABOUT SCIENCE AND ITS RELATION TO SOCIETY?"

| Class | Number and Percent* | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | Total |
| Yes | 16 (84) | 9(45) | 14(87) | 12 (57) | 51 (67) |
| No | 3 (16) | 11(55) | 2(13) | 9 (43) | 25 (33) |
| Total | 19(100) | 20(100) | 16(100) | 21(100) | 76(100) |

*Percentages are in parentheses.

TABLE 20

SCHOOL A - AMERICAN PROBLEMS CLASSES

STUDENT RESPONSES TO:
"WHICH CHAPTER WAS MOST INTERESTING AND LEAST INTERESTING TO YOU?"

| Chapter | Number and Percent* | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII | Totals |
| Most Interesting | 4 (03) | 6 (05) | 9 (09) | 3 (02) | 2 (01) | 2 (01) | 25 (24) | 3 (02) | 22 (21) | 19 (19) | 5 (04) | 7 (07) | 107 (99) |
| Least Interesting | 17 (17) | 14 (14) | 14 (14) | 11 (10) | 11 (10) | 6 (05) | 5 (04) | 13 (12) | 4 (03) | 2 (01) | 6 (05) | 4 (03) | 107 (100) |

TABLE 21

SCHOOL B - CHEMISTRY CLASSES

STUDENT RESPONSES TO:
"WHICH CHAPTER WAS MOST INTERESTING AND LEAST INTERESTING TO YOU?"

| Chapter | Number and Percent* | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII | Totals |
| Most Interesting | 1 (02) | 3 (04) | 2 (03) | 2 (03) | 2 (03) | 0 (--) | 12 (15) | 1 (02) | 29 (37) | 20 (25) | 1 (02) | 3 (04) | 76 (100) |
| Least Interesting | 11 (14) | 10 (13) | 6 (08) | 11 (14) | 10 (13) | 8 (10) | 1 (02) | 11 (14) | 1 (02) | 0 (--) | 4 (05) | 2 (04) | 76 (99) |

*Percentages are in parentheses.

TABLE 22

SCHOOL A - AMERICAN PROBLEMS CLASSES

STUDENT RESPONSES TO: "WHO WOULD BENEFIT FROM SCIENCE INSTRUCTION UTILIZING THIS TYPE OF APPROACH?"

| Class | Number and Percent* | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | Total |
| Science Career Students | 15 (58) | 9 (36) | 11 (37) | 13 (50) | 48 (44) |
| Non-Science Career Students | 3 (11) | 3 (12) | 3 (10) | 1 (04) | 10 (11) |
| All Students | 8 (30) | 12 (48) | 16 (53) | 12 (46) | 48 (44) |
| No High School Students | 0 (--) | 1 (04) | 0 (--) | 0 (--) | 1 (01) |
| Total | 26 (99) | 25(100) | 30(100) | 26(100) | 107(100) |

TABLE 23

SCHOOL B - CHEMISTRY CLASSES

STUDENT RESPONSES TO: "WHO WOULD BENEFIT FROM SCIENCE INSTRUCTION UTILIZING THIS TYPE OF APPROACH?"

| Class | Number and Percent* | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | Total |
| Science Career Students | 1 (05) | 2 (10) | 2 (12) | 2 (10) | 7 (09) |
| Non-Science Career Students | 1 (05) | 3 (15) | 1 (06) | 2 (10) | 7 (09) |
| All Students | 17 (90) | 15 (75) | 13 (81) | 17 (80) | 62 (82) |
| No High School Students | 0 (--) | 0 (--) | 0 (--) | 0 (--) | 0 (--) |
| Total | 19(100) | 20(100) | 16 (99) | 21(100) | 76(100) |

*Percentages are in parentheses.

TABLE 24

SCHOOL A - AMERICAN PROBLEMS CLASSES

STUDENT RESPONSES TO: " IF A COURSE UTILIZING THE SOCIO-HISTORICAL APPROACH WERE OFFERED WOULD YOU BE INTERESTED IN TAKING IT?"

| Class | Number and Percent* | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | Total |
| Yes | 13 (50) | 11 (44) | 17 (57) | 13 (50) | 54 (51) |
| No | 13 (50) | 14 (56) | 13 (43) | 13 (50) | 53 (49) |
| Total | 26(100) | 25(100) | 30(100) | 26(100) | 107(100) |

TABLE 25

SCHOOL B - CHEMISTRY CLASSES

STUDENT RESPONSES TO: "IF A COURSE UTILIZING THE SOCIO-HISTORICAL APPROACH WERE OFFERED WOULD YOU BE INTERESTED IN TAKING IT?"

| Class | Number and Percent* | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | Total |
| Yes | 18 (95) | 17 (85) | 15 (94) | 19 (90) | 69 (91) |
| No | 1 (05) | 3 (15) | 1 (06) | 2 (10) | 7 (09) |
| Total | 19(100) | 20(100) | 16(100) | 21(100) | 76(100) |

*Percentages are in parentheses.

4. Effect of the Unit Upon Student Understanding

Note from Tables 26 and 27 that in School A 91% and in School B 99% of the students expressed the opinion that the unit had increased their understanding of science and scientists. In addition, 83% of the students in American Problems Classes and 99% in Chemistry Classes reported an increase in understanding of the interrelationships of science and society (Tables 28 and 29). This same positive opinion persists relative to gain in understanding of the atom and atomic energy; 91% of School A and 100% of School B expressed a favorable response (Tables 30 and 31).

TABLE 26

SCHOOL A - AMERICAN PROBLEMS CLASSES

STUDENT RESPONSES TO: "WHAT EFFECT HAS THIS UNIT HAD ON YOUR UNDERSTANDING OF SCIENCE AND SCIENTISTS?"

| Class | Number and Percent* | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | Total |
| Increased Greatly | 7 (27) | 7 (28) | 10 (33) | 6 (23) | 30 (29) |
| Increased Somewhat | 15 (58) | 15 (60) | 16 (53) | 20 (77) | 66 (62) |
| No Improvement | 3 (11) | 2 (08) | 2 (07) | 0 (--) | 7 (06) |
| Confused Me | 1 (04) | 1 (04) | 2 (07) | 0 (--) | 4 (03) |
| Total | 26(100) | 25(100) | 30(100) | 26(100) | 107(100) |

TABLE 27

SCHOOL B - CHEMISTRY CLASSES

STUDENT RESPONSES TO: "WHAT EFFECT HAS THIS UNIT HAD ON YOUR UNDERSTANDING OF SCIENCE AND SCIENTISTS?"

| Class | Number and Percent* | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | Total |
| Increased Greatly | 10 (52) | 10 (50) | 9 (56) | 8 (38) | 37 (49) |
| Increased Somewhat | 9 (47) | 9 (45) | 7 (44) | 13 (62) | 38 (50) |
| No Improvement | 0 (--) | 1 (05) | 0 (--) | 0 (--) | 1 (01) |
| Confused Me | 0 (--) | 0 (--) | 0 (--) | 0 (--) | 0 (--) |
| Total | 19 (99) | 20(100) | 16(100) | 21(100) | 76(100) |

*Percentages are in parentheses.

TABLE 28

SCHOOL A - AMERICAN PROBLEMS CLASSES

STUDENT RESPONSES TO:
"WHAT EFFECT HAS THIS UNIT HAD ON YOUR UNDERSTANDING OF THE INTERRELATIONSHIPS OF SCIENCE AND SOCIETY?"

| Class | Number and Percent* | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | Total |
| Increased Greatly | 7 (27) | 2 (08) | 4 (13) | 3 (11) | 17 (16) |
| Increased Somewhat | 16 (62) | 16 (64) | 23 (76) | 18 (70) | 71 (67) |
| No Im-provement | 3 (11) | 6 (24) | 2 (07) | 5 (19) | 17 (16) |
| Confused Me | 0 (--) | 1 (04) | 1 (03) | 0 (--) | 2 (01) |
| Total | 26(100) | 25(100) | 30(100) | 26(100) | 107(100) |

TABLE 29

SCHOOL B - CHEMISTRY CLASSES

STUDENT RESPONSES TO:
"WHAT EFFECT HAS THIS UNIT HAD ON YOUR UNDERSTANDING OF THE INTERRELATIONSHIPS OF SCIENCE AND SOCIETY?"

| Class | Number and Percent* | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | Total |
| Increased Greatly | 14 (74) | 7 (35) | 12 (75) | 8 (38) | 41 (49) |
| Increased Somewhat | 5 (26) | 13 (65) | 4 (25) | 13 (62) | 35 (50) |
| No Im-provement | 0 (--) | 0 (--) | 0 (--) | 0 (--) | 0 (--) |
| Confused Me | 0 (--) | 0 (--) | 0 (--) | 0 (--) | 0 (--) |
| Total | 10(100) | 20(100) | 16(100) | 21(100) | 76(100) |

*Percentages are in parentheses.

TABLE 30

SCHOOL A - AMERICAN PROBLEMS CLASSES

STUDENT RESPONSES TO: "WHAT EFFECT HAS THIS UNIT HAD ON YOUR UNDERSTANDING OF THE ATOM AND ATOMIC ENERGY?"

| Class | Number and Percent* | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | Total |
| Increased Greatly | 11 (42) | 7 (28) | 7 (23) | 12 (46) | 37 (34) |
| Increased Somewhat | 13 (50) | 16 (64) | 19 (63) | 13 (05) | 61 (57) |
| No Improvement | 2 (08) | 2 (08) | 3 (10) | 1 (04) | 8 (08) |
| Confused Me | 0 (--) | 0 (--) | 1 (03) | 0 (--) | 1 (01) |
| Total | 26(100) | 25(100) | 30 (99) | 26(100) | 107(100) |

TABLE 31

SCHOOL B - CHEMISTRY CLASSES

STUDENT RESPONSES TO: "WHAT EFFECT HAS THIS UNIT HAD ON YOUR UNDERSTANDING OF THE ATOM AND ATOMIC ENERGY?"

| Class | Number and Percent* | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | Total |
| Increased Greatly | 14 (74) | 16 (80) | 12 (75) | 12 (57) | 54 (71) |
| Increased Somewhat | 5 (26) | 4 (20) | 4 (25) | 9 (43) | 22 (29) |
| No Improvement | 0 (--) | 0 (--) | 0 (--) | 0 (--) | 0 (--) |
| Confused Me | 0 (--) | 0 (--) | 0 (--) | 0 (--) | 0 (--) |
| Total | 19(100) | 20(100) | 16(100) | 21(100) | 76(100) |

*Percentages are in parentheses.

## 5. Other Questionnaire Results

### a. Time Devoted to Reading the Chapters

Although the average amount of time the individual student devoted to reading the chapters generally ranged from less than ½ hour to 1 hour per day (one student reported 1½ hours), a majority of the students reported ½ hour or less (Tables 32 and 33). It is noted from Tables 34 and 35 that the maximum amount of time spent studying any one chapter outside of class was 1½ hours or less with most students in both schools reporting 1 hour or less. This variation was probably due in part to the fact that some chapters were longer than others since most students reported that they had read most or all of each chapter (Tables 36 and 37).

As shown in Tables 36 and 37 the number of students that read most or all the chapters decreased but this number remained generally consistent after Chapter V. Since the students expressed a high level of interest in the unit, the decrease in the number of students reading the text materials is probably a reflection of the rapid pace at which the unit was presented--12 chapters over a period of 14 days. It is of interest to note, however, that some of the students apparently gained in subject matter knowledge from class participation only.

TABLE 32

SCHOOL A - AMERICAN PROBLEMS CLASSES

STUDENT RESPONSES TO: "ON THE AVERAGE, HOW MUCH TIME DID YOU SPEND READING EACH CHAPTER?"

| Class | Number and Percent* | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | Total |
| Less than ½ hour | 9 (34) | 6 (24) | 11 (37) | 9 (34) | 35 (33) |
| ½ hour | 12 (46) | 7 (28) | 11 (37) | 13 (50) | 43 (40) |
| 1 hour | 5 (20) | 12 (48) | 7 (23) | 4 (16) | 28 (26) |
| 1½ hours | 0 (--) | 0 (--) | 1 (03) | 0 (--) | 1 (01) |
| 2 hours or more | 0 (--) | 0 (--) | 0 (--) | 0 (--) | 0 (--) |
| Total | 26(100) | 25(100) | 30(100) | 26(100) | 107(100) |

TABLE 33

SCHOOL B - CHEMISTRY CLASSES

STUDENT RESPONSES TO: "ON THE AVERAGE, HOW MUCH TIME DID YOU SPEND READING EACH CHAPTER?"

| Class | Number and Percent* | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | Total |
| Less than ½ hour | 1 (05) | 3 (15) | 0 (--) | 3 (14) | 7 (09) |
| ½ hour | 13 (58) | 12 (60) | 13 (81) | 17 (81) | 55 (72) |
| 1 hour | 5 (26) | 5 (25) | 3 (19) | 1 (05) | 14 (19) |
| 1½ hours | 0 (--) | 0 (--) | 0 (--) | 0 (--) | 0 (--) |
| 2 hours or more | 0 (--) | 0 (--) | 0 (--) | 0 (--) | 0 (--) |
| Total | 19 (99) | 20(100) | 16(100) | 21 (99) | 76(100) |

*Percentages are in parentheses.

TABLE 34

SCHOOL A - AMERICAN PROBLEMS CLASSES

STUDENT RESPONSES TO: "WHAT WAS THE MAXIMUM AMOUNT OF TIME YOU SPENT READING ANY ONE CHAPTER?"

| Class | Number and Percent* | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | Total |
| Less than ½ hour | 3 (11) | 2 (08) | 6 (20) | 4 (15) | 14 (13) |
| ½ hour | 9 (34) | 3 (12) | 10 (33) | 7 (27) | 30 (28) |
| 1 hour | 11 (42) | 8 (32) | 38 (27) | 13 (50) | 40 (38) |
| 1½ hours | 2 (08) | 10 (40) | 6 (20) | 2 (08) | 20 (19) |
| 2 hours or more | 1 (04) | 2 (08) | 0 (--) | 0 (--) | 3 (02) |
| Total | 26 (99) | 25(100) | 30(100) | 26(100) | 107(100) |

TABLE 35

SCHOOL B - CHEMISTRY CLASSES

STUDENT RESPONSES TO: "WHAT WAS THE MAXIMUM AMOUNT OF TIME YOU SPENT READING ANY ONE CHAPTER?"

| Class | Number and Percent* | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | Total |
| Less than ½ hour | 0 (--) | 0 (--) | 0 (--) | 0 (--) | 0 (--) |
| ½ hour | 1 (05) | 3 (15) | 2 (12) | 1 (05) | 7 (09) |
| 1 hour | 11 (58) | 12 (60) | 9 (56) | 19 (90) | 51 (67) |
| 1½ hours | 7 (37) | 5 (25) | 5 (31) | 1 (05) | 18 (24) |
| 2 hours or more | 0 (--) | 0 (--) | 0 (--) | 0 (--) | 0 (--) |
| Total | 19(100) | 20(100) | 16 (99) | 21(100) | 76(100) |

*Percentages are in parentheses.

TABLE 36

SCHOOL A - AMERICAN PROBLEMS CLASSES

STUDENT RESPONSES TO: "TO WHAT EXTENT DID YOU READ EACH OF THE CHAPTERS?" (CHECK ONE FOR EACH CHAPTER)

| Chapter | Number and Percent* | | | |
|---|---|---|---|---|
| | All | Most | Some | None |
| I | 81 (75) | 13 (12) | 15 (14) | 0 (--) |
| II | 65 (60) | 24 (22) | 18 (17) | 0 (--) |
| III | 57 (53) | 26 (24) | 24 (22) | 0 (--) |
| IV | 50 (46) | 30 (28) | 24 (22) | 3 (02) |
| V | 45 (42) | 28 (26) | 31 (28) | 6 (05) |
| VI | 43 (40) | 26 (24) | 32 (29) | 6 (05) |
| VII | 43 (40) | 31 (28) | 29 (27) | 4 (03) |
| VIII | 44 (41) | 26 (24) | 27 (25) | 10 (09) |
| IX | 45 (42) | 32 (29) | 28 (26) | 4 (03) |
| X | 43 (40) | 26 (24) | 30 (28) | 8 (07) |
| XI | 44 (41) | 25 (23) | 28 (26) | 10 (09) |
| XII | 42 (39) | 27 (25) | 25 (23) | 13 (12) |

*Percentages are in parentheses.

TABLE 37

SCHOOL B - CHEMISTRY CLASSES

STUDENT RESPONSES TO: "TO WHAT EXTENT DID YOU READ EACH OF THE CHAPTERS?" (CHECK ONE FOR EACH CHAPTER)

| Chapter | Number and Percent* | | | |
|---|---|---|---|---|
| | All | Most | Some | None |
| I | 70 (92) | 5 (06) | 1 (02) | 0 (--) |
| II | 69 (91) | 6 (08) | 1 (02) | 0 (--) |
| III | 65 (85) | 10 (13) | 1 (02) | 0 (--) |
| IV | 56 (74) | 17 (22) | 3 (04) | 0 (--) |
| V | 52 (68) | 20 (26) | 3 (04) | 1 (02) |
| VI | 53 (70) | 19 (25) | 4 (05) | 0 (--) |
| VII | 56 (74) | 14 (18) | 6 (08) | 0 (--) |
| VIII | 53 (70) | 16 (21) | 7 (09) | 0 (--) |
| IX | 54 (71) | 16 (21) | 5 (06) | 1 (02) |
| X | 56 (74) | 15 (19) | 4 (05) | 1 (02) |
| XI | 50 (66) | 17 (22) | 6 (08) | 3 (04) |
| XII | 50 (66) | 16 (21) | 5 (06) | 4 (06) |

*Percentages are in parentheses.

<u>b. Comparison of the Unit to Other Science and Social Science Materials</u>

When the teaching materials and strategies were ranked in terms of their interest value some variation existed within both groups; however, the rankings of both groups were essentially the same except for the assessment of the <u>discussion of social implications</u>--the American Problems Classes ranked it as 4 and the Chemistry Classes ranked it as 1 (Table 38).

Tabulation of the opinions of the students relative to which activities they thought would help them to better understand the material in the unit, revealed about the same information in both schools; <u>more class discussion</u> ranked 1 and <u>more slides and movies</u> ranked 2 (Tables 39 and 40).

When asked to compare the reading materials prepared here with those in their other courses, a majority of students from both schools reported that the materials used in this study were easier or at least no more difficult than other science materials (Tables 41 and 42) and easier or at least no more difficult than other social science materials (Tables 43 and 44).

When the frame of reference was changed to how interesting the students found the materials, a majority of both groups again reported that the materials were more interesting or at least not less interesting than other science and social science materials studied (Tables 45, 46, 47, and 48).

TABLE 38

SCHOOL A - AMERICAN PROBLEMS CLASSES
AND
SCHOOL B - CHEMISTRY CLASSES

STUDENT RESPONSES TO: "LIST THE FOLLOWING ITEMS IN THE ORDER OF INTEREST TO YOU."

| | Number and Percent* | | | | |
|---|---|---|---|---|---|
| | Scientific Explanation | History | Biographies | Quotations | Social Implications |
| SCHOOL A | | | | | |
| Most Interesting.......... | 21 (19) | 40 (37) | 22 (20) | 0 (--) | 24 (22) |
| Rank Order................ | 3 | 1 | 2 | 5 | 4 |
| Least Interesting......... | 25 (23) | 15 (14) | 11 (10) | 35 (32) | 21 (19) |
| SCHOOL B | | | | | |
| Most Interesting.......... | 16 (21) | 18 (23) | 15 (20) | 0 (--) | 27 (35) |
| Rank Order................ | 4 | 2 | 3 | 5 | 1 |
| Least Interesting......... | 15 (20) | 7 (09) | 10 (13) | 35 (46) | 8 (10) |

*Percentages are in parentheses.

TABLE 39

SCHOOL A - AMERICAN PROBLEMS CLASSES

STUDENT RESPONSES TO:
"WHICH OF THE FOLLOWING DO YOU THINK WOULD HAVE HELPED YOU TO BETTER UNDERSTAND THE MATERIAL IN THIS UNIT?"

| Class | Number and Percent* | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | Total |
| More Class Discussion | 13 (50) | 16 (64) | 12 (40) | 17 (65) | 58 (55) |
| More Lecture Explanation | 2 (08) | 2 (08) | 3 (11) | 2 (08) | 9 (08) |
| More Slides and Movies | 7 (27) | 2 (08) | 10 (30) | 5 (19) | 24 (23) |
| More Recitation-Drill | 4 (15) | 2 (08) | 2 (08) | 0 (--) | 8 (07) |
| More Reading | 0 (--) | 3 (12) | 3 (11) | 2 (08) | 8 (07) |
| Total | 26(100) | 25(100) | 30(100) | 26(100) | 107(100) |

TABLE 40

SCHOOL B - CHEMISTRY CLASSES

STUDENT RESPONSES TO:
"WHICH OF THE FOLLOWING DO YOU THINK WOULD HAVE HELPED YOU TO BETTER UNDERSTAND THE MATERIAL IN THIS UNIT?"

| Class | Number and Percent* | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | Total |
| More Class Discussion | 7 (37) | 7 (35) | 6 (37) | 8 (38) | 28 (37) |
| More Lecture Explanation | 3 (16) | 2 (10) | 5 (31) | 5 (23) | 15 (20) |
| More Slides and Movies | 9 (47) | 7 (35) | 2 (13) | 6 (29) | 24 (31) |
| More Recitation-Drill | 0 (--) | 3 (15) | 2 (13) | 2 (10) | 7 (09) |
| More Reading | 0 (--) | 1 (05) | 1 (06) | 0 (--) | 2 (03) |
| Total | 19(100) | 20(100) | 16(100) | 21(100) | 76(100) |

*Percentages are in parentheses.

TABLE 41

SCHOOL A - AMERICAN PROBLEMS CLASSES

STUDENT RESPONSES TO:
"WHEN COMPARED TO MOST SCIENCE MATERIALS YOU HAVE READ BEFORE, THE READING MATERIAL FOR THIS UNIT IS:"

| Class | Number and Percent* | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | Total |
| Much More Difficult | 1 (04) | 0 (--) | 1 (03) | 1 (04) | 3 (02) |
| Somewhat More Difficult | 3 (11) | 4 (16) | 2 (07) | 1 (04) | 9 (08) |
| About the Same Difficulty | 3 (11) | 4 (16) | 6 (20) | 1 (04) | 14 (13) |
| Somewhat Easier | 14 (54) | 14 (56) | 13 (43) | 17 (66) | 58 (55) |
| Much Easier | 5 (19) | 3 (12) | 8 (27) | 6 (22) | 23 (21) |
| Total | 26 (99) | 25(100) | 30(100) | 26(100) | 107 (99) |

TABLE 42

SCHOOL B - CHEMISTRY CLASSES

STUDENT RESPONSES TO:
"WHEN COMPARED TO MOST SCIENCE MATERIALS YOU HAVE READ BEFORE, THE READING MATERIAL FOR THIS UNIT IS:"

| Class | Number and Percent* | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | Total |
| Much More Difficult | 0 (--) | 0 (--) | 0 (--) | 0 (--) | 0 (--) |
| Somewhat More Difficult | 0 (--) | 0 (--) | 13 (81) | 0 (--) | 0 (--) |
| About the Same Difficulty | 1 (05) | 2 (10) | 3 (19) | 2 (10) | 8 (10) |
| Somewhat Easier | 11 (58) | 7 (35) | 0 (--) | 15 (71) | 41 (54) |
| Much Easier | 7 (37) | 11 (55) | 0 (--) | 4 (19) | 27 (35) |
| Total | 19(100) | 20(100) | 16(100) | 21(100) | 76 (99) |

*Percentages are in parentheses.

TABLE 43

SCHOOL A - AMERICAN PROBLEMS CLASSES

STUDENT RESPONSES TO:
"WHEN COMPARED TO MOST SOCIAL SCIENCE MATERIALS YOU HAVE READ BEFORE, THIS READING MATERIAL IS:"

| Class | Number and Percent* | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | Total |
| Much More Difficult | 1 (04) | 0 (--) | 0 (--) | 0 (--) | 1 (01) |
| Somewhat More Difficult | 3 (11) | 3 (12) | 2 (07) | 2 (08) | 10 (09) |
| About the Same Difficulty | 3 (11) | 20 (80) | 11 (37) | 9 (34) | 46 (43) |
| Somewhat Easier | 14 (54) | 2 (08) | 13 (43) | 14 (54) | 42 (39) |
| Much Easier | 5 (19) | 0 (--) | 4 (13) | 1 (04) | 8 (07) |
| Total | 26 (99) | 25(100) | 30(100) | 26(100) | 107 (99) |

TABLE 44

SCHOOL B - CHEMISTRY CLASSES

STUDENT RESPONSES TO:
"WHEN COMPARED TO MOST SOCIAL SCIENCE MATERIALS YOU HAVE READ BEFORE, THIS READING MATERIAL IS:"

| Class | Number and Percent* | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | Total |
| Much More Difficult | 0 (--) | 0 (--) | 0 (--) | 0 (--) | 0 (--) |
| Somewhat More Difficult | 1 (05) | 0 (--) | 0 (--) | 2 (10) | 3 (04) |
| About the Same Difficulty | 9 (47) | 4 (20) | 2 (12) | 12 (57) | 27 (35) |
| Somewhat Easier | 8 (42) | 7 (35) | 12 (75) | 6 (29) | 33 (43) |
| Much Easier | 1 (05) | 9 (45) | 2 (12) | 1 (04) | 13 (17) |
| Total | 19 (99) | 20(100) | 16 (99) | 21(100) | 76 (99) |

*Percentages are in parentheses.

TABLE 45

SCHOOL A - AMERICAN PROBLEMS CLASSES

STUDENT RESPONSES TO: "WHEN COMPARED TO OTHER SCIENCE MATERIALS, THIS UNIT IS:"

| Class | Number and Percent * | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | Total |
| Much Less Interesting | 1 (04) | 0 (--) | 1 (03) | 0 (--) | 2 (01) |
| Somewhat Less Interesting | 1 (04) | 6 (24) | 2 (06) | 1 (04) | 10 (09) |
| About the Same | 13 (50) | 7 (28) | 11 (37) | 10 (38) | 41 (39) |
| Somewhat More Interesting | 7 (27) | 11(44) | 14 (47) | 9 (34) | 41 (39) |
| Much More Interesting | 4 (15) | 1 (04) | 2 (07) | 6 (23) | 13 (12) |
| Total | 26(100) | 25(100) | 30(100) | 26 (99) | 107(100) |

TABLE 46

SCHOOL B - CHEMISTRY CLASSES

STUDENT RESPONSES TO: "WHEN COMPARED TO OTHER SCIENCE MATERIALS, THIS UNIT IS:"

| Class | Number and Percent* | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | Total |
| Much Less Interesting | 0 (--) | 0 (--) | 0 (--) | 0 (--) | 0 (--) |
| Somewhat Less Interesting | 0 (--) | 0 (--) | 0 (--) | 0 (--) | 0 (--) |
| About the Same | 1 (05) | 1 (05) | 0 (--) | 0 (--) | 2 (03) |
| Somewhat More Interesting | 4 (21) | 6 (30) | 9 (56) | 10 (48) | 29 (38) |
| Much More Interesting | 14 (74) | 13 (65) | 7 (44) | 11 (52) | 45 (59) |
| Total | 19(100) | 20(100) | 16(100) | 21(100) | 76(100) |

*Percentages are in parentheses.

TABLE 47

SCHOOL A - AMERICAN PROBLEMS CLASSES

STUDENT RESPONSES TO: "WHEN COMPARED TO OTHER SOCIAL SCIENCE MATERIALS, THIS UNIT IS:"

| Class | Number and Percent* | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | Total |
| Much Less Interesting | 3 (11) | 1 (04) | 4 (13) | 1 (04) | 10 (09) |
| Somewhat Less Interesting | 2 (08) | 5 (20) | 3 (10) | 3 (11) | 13 (12) |
| About the Same | 9 (34) | 10 (40) | 10 (33) | 14 (54) | 43 (40) |
| Somewhat More Interesting | 7 (27) | 8 (32) | 9 (30) | 5 (19) | 28 (26) |
| Much More Interesting | 5 (19) | 1 (04) | 4 (13) | 3 (11) | 13 (12) |
| Total | 26 (99) | 25(100) | 30 (99) | 26 (99) | 107(100) |

TABLE 48

SCHOOL B - CHEMISTRY CLASSES

STUDENT RESPONSES TO: "WHEN COMPARED TO OTHER SOCIAL SCIENCE MATERIALS, THIS UNIT IS:"

| Class | Number and Percent* | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | Total |
| Much Less Interesting | 0 (--) | 0 (--) | 0 (--) | 0 (--) | 0 (--) |
| Somewhat Less Interesting | 0 (--) | 1 (05) | 0 (--) | 1 (05) | 2 (03) |
| About the Same | 4 (21) | 2 (10) | 2 (12) | 7 (33) | 15 (20) |
| Somewhat More Interesting | 11(58) | 10 (50) | 7 (44) | 10 (48) | 38 (50) |
| Much More Interesting | 4 (21) | 7 (35) | 7 (44) | 3 (14) | 21 (27) |
| Total | 19(100) | 20(100) | 16(100) | 21(100) | 76(100) |

*Percentages are in parentheses.

## 6. Correlation of Student Gains and IQ

The differences in student gains within a group or within a class do not appear to be explainable using IQ since there is no consistent pattern of relationship between student gains and IQ for either school (Tables 49 and 50). The fact that the correlations between student gains and IQ in School B are low positive or negative rather than high positive may indicate that the students in School B are highly motivated or that IQ is not an important factor beyond some unknown minimum. The correlation coefficients for School A are low positive and provide little to support or deny the apparent independence of the student gains from IQ.

TABLE 49

SCHOOL A - AMERICAN PROBLEMS CLASSES

CORRELATIONS BETWEEN IQ AND STUDENT GAINS

| Class | Gains | | | |
|---|---|---|---|---|
| | Subtest a | Subtest b | Subtest c | Total Test |
| (1) | .477 | .205 | .057 | .363 |
| (2) | .121 | .206 | -.009 | .159 |
| (3) | -.133 | .306 | .073 | .126 |
| (4) | .276 | .302 | .125 | .315 |
| All Classes | .154 | .262 | .076 | .232 |

TABLE 50

SCHOOL B - CHEMISTRY CLASSES

CORRELATIONS BETWEEN IQ AND STUDENT GAINS

| Class | Gains | | | |
|---|---|---|---|---|
| | Subtest a | Subtest b | Subtest c | Total Test |
| (1) | .000 | .117 | -.558 | -.300 |
| (2) | .006 | -.351 | -.133 | -.259 |
| (3) | .229 | .013 | -.186 | .086 |
| (4) | -.007 | -.047 | -.318 | -.200 |
| All Classes | .096 | -.187 | -.254 | -.181 |

## CHAPTER V. CONCLUSIONS AND IMPLICATIONS

### Conclusions

The conclusions formulated here are restricted to the conditions of the study, namely the procedures utilized and the nature of the populations included.

Teaching science via a socio-historical approach utilizing selected concepts related to the social and historical development of science and selected concepts related to atomic energy <u>is feasible</u> as indicated by the following facts. In School A (American Problems Classes) and School B (Chemistry Classes),

1. There was a significant increase in subject matter knowledge related to

   a. science and scientists,

   b. the interrelationships of science and society, and

   c. the atom and atomic energy, possessed by students in the study as indicated by comparison of pretest and posttest scores.

2. A majority of the students are interested in participating in a course that is designed to show interrelationships of science and society, and are interested in

reading more about science and its relationships to society.

3. A majority of the students are of the opinion that their interest in science had been maintained or increased during the study of this unit.

4. A majority of the students expressed the opinion that the reading material of the unit was

a. more interesting than most other reading materials in science,

b. at least as interesting as reading materials in social science,

c. less difficult than most other reading materials in science, and

d. no more difficult than reading materials in social science with which they were familiar.

5. Students receiving instruction utilizing the socio-historical approach expressed a desire for greater student participation through more class discussion.

6. A majority of students enrolled reported that the unit increased their understanding of

a. science and scientists,

b. the interrelationships of science and society, and

c. the atom and atomic energy.

7. The correlation coefficients between student gains and IQ do not exhibit any consistent pattern and indicate

little or no relationship between success in this unit and IQ.

Table 51 summarizes the performance of Schools A and B in regard to the criteria of acceptance.

TABLE 51

SCHOOL A - AMERICAN PROBLEMS CLASSES
AND
SCHOOL B - CHEMISTRY CLASSES

SUMMARY OF CRITERIA FOR ACCEPTANCE AND
THE PERFORMANCE OF THE SCHOOLS
IN MEETING THESE CRITERIA

| Criterion | School A | School B |
|---|---|---|
| 1. Significant increase in subject matter knowledge as indicated by total test and subtests. | Yes | Yes |
| 2. High level of student interest in the unit (student opinions). | Yes | Yes |
| 3. Increase in student understanding of subject matter (student opinions). | Yes | Yes |

## Implications

The results of the study suggest the following implications:

1. Central themes such as the development of atomic energy and its social implications provide effective vehicles for the development and presentation of concepts that emphasize the social implications of science.

2. Science-society interrelationships, such as those presented in this study, can be distinguished and isolated from the total social milieu and can be taught to some portion of the high school population.

3. High school populations exist that can benefit from science instruction via a socio-historical approach.

4. The favorable student response to the presentation of slides--with accompanying narrative and class discussion--supports the implication stated by Boles (1968) that the technique of slide presentation is an effective method of presenting subject matter in a unit utilizing the socio-historical approach.

5. The unfavorable student response to quotations of scientists tends to contradict the inference made by some developers of instructional materials that selected quotations of scientists promote student interest in science taught by a historical or case study approach.

6. There is a need for additional research pertaining

to the socio-historical approach to science instruction in regard to other *in vitro* classroom situations.

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# APPENDIX A

## TABLES FOR SCHOOL A - AMERICAN PROBLEMS CLASSES

Table 1.

Reliabilities for Subtests and Total Test
for School A--American Problems Classes
(Hoyt ANOVA for Internal Consistency)

| Reliability | Subtest a | Subtest b | Subtest c | Total Test |
|---|---|---|---|---|
| Pretest | .603 | .566 | .652 | .810 |
| Posttest | .730 | .746 | .818 | .903 |

Table 2.

Number and Proportion of Students Answering Each Item Correctly on Pretest and Posttest for Concepts Related to Science and Scientists

School A--American Problems Classes (N = 107)

| Question | Number and Proportion | Question | Number and Proportion |
|---|---|---|---|
| 1 Pre | 58 (.54) | 46 Pre | 71 (.66) |
| 1 Post | 75 (.70) | 46 Post | 65 (.60)** |
| 2 Pre | 80 (.74) | 47 Pre | 22 (.20) |
| 2 Post | 84 (.78) | 47 Post | 45 (.42) |
| 3 Pre | 54 (.50) | 48 Pre | 9 (.08) |
| 3 Post | 77 (.71) | 48 Post | 9 (.08)* |
| 4 Pre | 54 (.50) | 49 Pre | 63 (.58) |
| 4 Post | 72 (.67) | 49 Post | 71 (.65) |
| 5 Pre | 47 (.44) | 50 Pre | 26 (.24) |
| 5 Post | 75 (.70) | 50 Post | 55 (.51) |
| 6 Pre | 15 (.14) | 51 Pre | 58 (.54) |
| 6 Post | 44 (.41) | 51 Post | 54 (.51)** |
| 7 Pre | 36 (.34) | 52 Pre | 75 (.70) |
| 7 Post | 66 (.61) | 52 Post | 98 (.91) |
| 8 Pre | 13 (.12) | 53 Pre | 49 (.45) |
| 8 Post | 27 (.11) | 53 Post | 51 (.47) |
| 9 Pre | 49 (.45) | 54 Pre | 31 (.28) |
| 9 Post | 62 (.57) | 54 Post | 48 (.44) |
| 10 Pre | 96 (.89) | 55 Pre | 46 (.43) |
| 10 Post | 101 (.94) | 55 Post | 72 (.67) |
| 11 Pre | 53 (.49) | 56 Pre | 45 (.42) |
| 11 Post | 39 (.36)** | 56 Post | 54 (.49) |
| 12 Pre | 50 (.47) | 57 Pre | 7 (.06) |
| 12 Post | 72 (.67) | 57 Post | 26 (.24) |

*No Change
**Decrease

Table 2.(continued)

| Question | Number and Proportion | Question | Number and Proportion |
|---|---|---|---|
| 13 Pre | 37 (.34) | 58 Pre | 62 (.58) |
| 13 Post | 44 (.41) | 58 Post | 76 (.71) |
| 14 Pre | 52 (.48) | 59 Pre | 35 (.32) |
| 14 Post | 52 (.48)* | 59 Post | 44 (.41) |
| 15 Pre | 21 (.19) | 60 Pre | 47 (.44) |
| 15 Post | 56 (.52) | 60 Post | 67 (.62) |

* No Change
**Decrease

Table 3.

Number and Proportion of Students Answering Each Item Correctly on Pretest and Posttest for Concepts Related to Science and Society

School A--American Problems Classes (N = 107)

| Question | Number and Proportion | Question | Number and Proportion |
|---|---|---|---|
| 16 Pre | 12 (.11) | 61 Pre | 28 (.26) |
| 16 Post | 37 (.34) | 61 Post | 48 (.44) |
| 17 Pre | 15 (.14) | 62 Pre | 17 (.15) |
| 17 Post | 54 (.50) | 62 Post | 40 (.37) |
| 18 Pre | 18 (.16) | 63 Pre | 3 (.02) |
| 18 Post | 19 (.17) | 63 Post | 10 (.09) |
| 19 Pre | 31 (.29) | 64 Pre | 18 (.16) |
| 19 Post | 74 (.69) | 64 Post | 31 (.29) |
| 20 Pre | 50 (.46) | 65 Pre | 7 (.06) |
| 20 Post | 61 (.57) | 65 Post | 29 (.27) |
| 21 Pre | 75 (.70) | 66 Pre | 16 (.14) |
| 21 Post | 76 (.71) | 66 Post | 19 (.17) |
| 22 Pre | 47 (.44) | 67 Pre | 86 (.80) |
| 22 Pre | 70 (.65) | 67 Post | 89 (.82) |
| 23 Pre | 54 (.50) | 68 Pre | 43 (.40) |
| 23 Post | 55 (.51) | 68 Post | 69 (.64) |
| 24 Pre | 29 (.27) | 69 Pre | 41 (.38) |
| 24 Post | 65 (.60) | 69 Post | 51 (.47) |
| 25 Pre | 27 (.25) | 70 Pre | 43 (.40) |
| 25 Post | 32 (.29) | 70 Post | 53 (.48) |
| 26 Pre | 52 (.48) | 71 Pre | 23 (.21) |
| 26 Post | 79 (.65) | 71 Post | 45 (.42) |

Table 3. (continued)

| Question | Number and Proportion | Question | Number and Proportion |
|---|---|---|---|
| 27 Pre | 62 (.58) | 72 Pre | 32 (.30) |
| 27 Post | 83 (.77) | 72 Post | 26 (.24)** |
| 28 Pre | 7 (.06) | 73 Pre | 76 (.71) |
| 28 Post | 73 (.68) | 73 Post | 77 (.71) |
| 29 Pre | 32 (.29) | 74 Pre | 45 (.42) |
| 29 Post | 42 (.39) | 74 Post | 65 (.60) |
| 30 Pre | 54 (.50) | 75 Pre | 25 (.23) |
| 30 Post | 61 (.57) | 75 Post | 35 (.32) |

*No Change
**Decrease

Table 4.

Number and Proportion of Students Answering Each Item Correctly on Pretest and Posttest for Concepts Related to Atoms and Atomic Energy

School A--American Problems Classes (N = 107)

| Question | Number and Proportion | Question | Number and Proportion |
|---|---|---|---|
| 31 Pre | 35 (.33) | 76 Pre | 55 (.51) |
| 31 Post | 45 (.42) | 76 Post | 72 (.67) |
| 32 Pre | 21 (.19) | 77 Pre | 35 (.33) |
| 32 Post | 64 (.59) | 77 Post | 74 (.68) |
| 33 Pre | 61 (.57) | 78 Pre | 28 (.26) |
| 33 Post | 78 (.72) | 78 Post | 53 (.49) |
| 34 Pre | 43 (.40) | 79 Pre | 31 (.28) |
| 34 Post | 56 (.52) | 79 Post | 45 (.41) |
| 35 Pre | 57 (.53) | 80 Pre | 35 (.32) |
| 35 Post | 77 (.72) | 80 Post | 41 (.38) |
| 36 Pre | 55 (.51) | 81 Pre | 22 (.20) |
| 36 Post | 77 (.72) | 81 Post | 44 (.41) |
| 37 Pre | 26 (.24) | 82 Pre | 59 (.55) |
| 37 Post | 42 (.39) | 82 Post | 62 (.57) |
| 38 Pre | 59 (.55) | 83 Pre | 55 (.51) |
| 38 Post | 79 (.73) | 83 Post | 76 (.70) |
| 39 Pre | 61 (.57) | 84 Pre | 65 (.61) |
| 39 Post | 72 (.67) | 84 Post | 80 (.73) |
| 40 Pre | 25 (.23) | 85 Pre | 49 (.46) |
| 40 Post | 52 (.48) | 85 Post | 76 (.70) |
| 41 Pre | 57 (.53) | 86 Pre | 61 (.57) |
| 41 Post | 74 (.69) | 86 Post | 75 (.69) |
| 42 Pre | 54 (.50) | 87 Pre | 27 (.25) |
| 42 Post | 56 (.52) | 87 Post | 32 (.29) |

Table 4. (continued)

| Question | Number and Proportion | Question | Number and Proportion |
|---|---|---|---|
| 43 Pre | 29 (.27) | 88 Pre | 46 (.43) |
| 43 Post | 55 (.51) | 88 Post | 72 (.67) |
| 44 Pre | 74 (.69) | 89 Pre | 41 (.38) |
| 44 Post | 85 (.79) | 89 Post | 60 (.55) |
| 45 Pre | 84 (.78) | 90 Pre | 29 (.27) |
| 45 Post | 97 (.90) | 90 Post | 35 (.32) |

TABLE 5. ITEM STATISTICS OF TOTAL TEST FOR SCHOOL A - AMERICAN PROBLEMS CLASSES (POSTTEST).

| Item | Choice | Wt | NR | Difficulty | R | X50 | β |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 20. | .1869 | -.3363 | -2.6447 | -.3571 |
| 1 | 2 | 0 | 2. | .0187 | -.2082 | -9.9984 | -.2129 |
| 1 | 3 | 0 | 2. | .0187 | -.4198 | -4.9588 | -.4625 |
| 1 | 4 | 0 | 8. | .0748 | -.2158 | -6.6798 | -.2210 |
| 1 | 5 | 1 | 75. | .7009 | .4306 | -1.2241 | .4771 |
| 2 | 1 | 0 | 6. | .0561 | -.4668 | -3.4030 | -.5279 |
| 2 | 2 | 0 | 3. | .0280 | -.3186 | -5.9964 | -.3361 |
| 2 | 3 | 1 | 84. | .7850 | .3226 | -2.4469 | .3408 |
| 2 | 4 | 0 | 4. | .0374 | -.1063 | -16.7587 | -.1069 |
| 2 | 5 | 0 | 10. | .0935 | -.0740 | -17.8431 | -.0742 |
| 3 | 1 | 0 | 12. | .1121 | -.4010 | -3.0307 | -.4377 |
| 3 | 2 | 0 | 14. | .1308 | -.4241 | -2.6469 | -.4682 |
| 3 | 3 | 1 | 77. | .7196 | .6084 | -9562 | .7666 |
| 3 | 4 | 0 | 2. | .0187 | -.6616 | -3.1464 | -.8822 |
| 3 | 5 | 0 | 2. | .0187 | -.1780 | -11.6965 | -.1809 |
| 4 | 1 | 0 | 11. | .1028 | -.6125 | -2.0664 | -.7749 |
| 4 | 2 | 0 | 16. | .1495 | -.3896 | -2.6656 | -.4230 |
| 4 | 3 | 0 | 2. | .0187 | -.2838 | -7.3358 | -.2959 |
| 4 | 4 | 1 | 72. | .6729 | .6243 | -.7175 | .7991 |
| 4 | 5 | 0 | 6. | .0561 | -.1060 | -14.9903 | -.1066 |
| 5 | 1 | 0 | 9. | .0841 | -.3311 | -4.1618 | -.3509 |
| 5 | 2 | 1 | 75. | .7009 | .5082 | -1.0372 | .5901 |
| 5 | 3 | 0 | 9. | .0841 | -.1342 | -10.2677 | -.1354 |
| 5 | 4 | 0 | 14. | .1308 | -.4923 | -2.2798 | -.5656 |
| 5 | 5 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 6 | 1 | 0 | 9. | .0841 | -.5504 | -2.5037 | -.6592 |
| 6 | 2 | 1 | 44. | .4112 | .4954 | .4531 | .5702 |
| 6 | 3 | 0 | 3. | .0280 | -.3616 | -5.2839 | -.3878 |
| 6 | 4 | 0 | 7. | .0654 | -.4674 | -3.2323 | -.5287 |
| 6 | 5 | 0 | 44. | .4112 | -.0640 | -3.5040 | -.0642 |
| 7 | 1 | 0 | 15. | .1402 | -.0568 | -19.0034 | -.0569 |
| 7 | 2 | 0 | 7. | .0654 | -.2831 | -5.3370 | -.2952 |
| 7 | 3 | 0 | 7. | .0654 | -.1313 | -11.5083 | -.1324 |
| 7 | 4 | 0 | 12. | .1121 | -.3865 | -3.1444 | -.4190 |
| 7 | 5 | 1 | 66. | .6168 | .3645 | -.8152 | .3914 |
| 8 | 1 | 0 | 24. | .2243 | -.3376 | -2.2444 | -.3587 |
| 8 | 2 | 0 | 2. | .0187 | -.5104 | -4.0779 | -.5936 |
| 8 | 3 | 0 | 50. | .4673 | .0671 | 1.2236 | .0672 |
| 8 | 4 | 1 | 27. | .2523 | .3440 | 1.9392 | .3664 |
| 8 | 5 | 0 | 4. | .0374 | -.1487 | -11.9846 | -.1504 |

TABLE 5. (CONTINUED)

| Item | Choice | Wt | NR | Difficulty | R | X50 | β |
|---|---|---|---|---|---|---|---|
| 9 | 1 | 0 | 27. | .2523 | .0066 | 101.8451 | .0066 |
| 9 | 2 | 0 | 11. | .1028 | -.0184 | -68.8326 | -.0184 |
| 9 | 3 | 0 | 5. | .0467 | -.1870 | -8.9726 | -.1903 |
| 9 | 4 | 0 | 2. | .0187 | .0034 | 614.0666 | .0034 |
| 9 | 5 | 1 | 62. | .5794 | .0494 | -4.0588 | .0494 |
| 10 | 1 | 0 | 1. | .0093 | -.4644 | -5.0637 | -.5244 |
| 10 | 2 | 1 | 101. | .9439 | .6931 | -2.2919 | .9616 |
| 10 | 3 | 0 | 2. | .0187 | -.6162 | -3.3779 | -.7825 |
| 10 | 4 | 0 | 3. | .0280 | -.5979 | -3.1955 | -.7458 |
| 10 | 5 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 11 | 1 | 0 | 24. | .2243 | .0154 | 49.0729 | .0154 |
| 11 | 2 | 0 | 10. | .0935 | -.0864 | -15.2793 | -.0867 |
| 11 | 3 | 1 | 39. | .3645 | .1055 | 3.2843 | .1061 |
| 11 | 4 | 0 | 7. | .0654 | -.1801 | -8.3900 | -.1831 |
| 11 | 5 | 0 | 27. | .2523 | -.0216 | -30.9259 | -.0216 |
| 12 | 1 | 0 | 7. | .0654 | -.0662 | -22.8140 | -.0664 |
| 12 | 2 | 0 | 11. | .1028 | -.2036 | -6.2176 | -.2079 |
| 12 | 3 | 0 | 6. | .0561 | -.4546 | -3.4945 | -.5104 |
| 12 | 4 | 0 | 11. | .1028 | -.3425 | -3.6960 | -.3645 |
| 12 | 5 | 1 | 72. | .6729 | .4366 | -1.0259 | .4853 |
| 13 | 1 | 1 | 44. | .4112 | .3515 | .6385 | .3755 |
| 13 | 2 | 0 | 11. | .1028 | -.2807 | -4.5087 | -.2925 |
| 13 | 3 | 0 | 9. | .0841 | -.2147 | -6.4165 | -.2199 |
| 13 | 4 | 0 | 15. | .1402 | -.4196 | -2.5725 | -.4623 |
| 13 | 5 | 0 | 28. | .2617 | .1234 | 5.1707 | .1244 |
| 14 | 1 | 0 | 9. | .0841 | -.4698 | -2.9330 | -.5322 |
| 14 | 2 | 0 | 38. | .3551 | -.3725 | -.9974 | -.4013 |
| 14 | 3 | 1 | 52. | .4860 | .4918 | .0715 | .5649 |
| 14 | 4 | 0 | 1. | .0093 | -.2444 | -9.6215 | -.2521 |
| 14 | 5 | 0 | 7. | .0654 | .1669 | 9.0522 | .1693 |
| 15 | 1 | 0 | 3. | .0280 | -.1790 | -10.6744 | -.1819 |
| 15 | 2 | 0 | 14. | .1308 | -.1445 | -7.7703 | -.1460 |
| 15 | 3 | 0 | 6. | .0561 | -.2956 | -5.3746 | -.3094 |
| 15 | 4 | 1 | 56. | .5234 | .4185 | -.1400 | .4609 |
| 15 | 5 | 0 | 28. | .2617 | -.2799 | -2.2799 | -.2916 |
| 16 | 1 | 0 | 10. | .0935 | -.3139 | -4.2042 | -.3306 |
| 16 | 2 | 0 | 9. | .0841 | -.1387 | -9.9364 | -.1400 |
| 16 | 3 | 0 | 21. | .1963 | -.3036 | -2.8162 | -.3187 |
| 16 | 4 | 0 | 30. | .2804 | -.1182 | -4.9212 | -.1190 |
| 16 | 5 | 1 | 37. | .3458 | .5361 | .7400 | .6351 |

TABLE 5. (CONTINUED)

| Item | Choice | Wt | NR | Difficulty | R | X50 | β |
|---|---|---|---|---|---|---|---|
| 17 | 1 | 0 | 7. | .0654 | -.3210 | -4.7061 | -.3390 |
| 17 | 2 | 0 | 33. | .3084 | -.3225 | -1.5517 | -.3407 |
| 17 | 3 | 0 | 5. | .0467 | -.3213 | -5.2208 | -.3393 |
| 17 | 4 | 1 | 54. | .5047 | .5647 | -.0207 | .6842 |
| 17 | 5 | 0 | 8. | .0748 | -.2793 | -5.1591 | -.2909 |
| 18 | 1 | 1 | 19. | .1776 | -.2546 | -3.6322 | -.2632 |
| 18 | 2 | 0 | 4. | .0374 | -.4452 | -4.0027 | -.4972 |
| 18 | 3 | 0 | 21. | .1963 | -.0840 | -10.1822 | -.0843 |
| 18 | 4 | 0 | 28. | .2617 | .1298 | 4.9170 | .1309 |
| 18 | 5 | 0 | 35. | .3271 | .2315 | 1.9349 | .2380 |
| 19 | 1 | 1 | 74. | .6916 | .4579 | -1.0928 | .5150 |
| 19 | 2 | 0 | 22. | .2056 | -.4722 | -1.7404 | -.5356 |
| 19 | 3 | 0 | 6. | .0561 | -.0937 | -16.9463 | -.0942 |
| 19 | 4 | 0 | 5. | .0467 | -.1657 | -10.1210 | -.1681 |
| 19 | 5 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 20 | 1 | 0 | 26. | .2430 | -.4991 | -1.3961 | -.5759 |
| 20 | 2 | 1 | 61. | .5701 | .6611 | -.2672 | .8811 |
| 20 | 3 | 0 | 11. | .1028 | -.2499 | -5.0656 | -.2581 |
| 20 | 4 | 0 | 2. | .0187 | -.3895 | -5.3436 | -.4230 |
| 20 | 5 | 0 | 7. | .0654 | -.3210 | -4.7061 | -.3390 |
| 21 | 1 | 0 | 9. | .0841 | -.3177 | -4.3377 | -.3350 |
| 21 | 2 | 0 | 13. | .1215 | -.1970 | -5.9266 | -.2009 |
| 21 | 3 | 0 | 8. | .0748 | -.2940 | -4.9016 | -.3076 |
| 21 | 4 | 0 | 1. | .0093 | -.4919 | -4.7806 | -.5650 |
| 21 | 5 | 1 | 76. | .7103 | .4170 | -1.3290 | .4588 |
| 22 | 1 | 0 | 7. | .0654 | -.4023 | -3.7549 | -.4395 |
| 22 | 2 | 1 | 70. | .6542 | .4793 | -.8276 | .5462 |
| 22 | 3 | 0 | 5. | .0467 | -.4981 | -3.3678 | -.5744 |
| 22 | 4 | 0 | 3. | .0280 | -.2541 | -7.5168 | -.2628 |
| 22 | 5 | 0 | 22. | .2056 | -.2125 | -3.8678 | -.2174 |
| 23 | 1 | 0 | 20. | .1869 | -.5060 | -1.7576 | -.5866 |
| 23 | 2 | 0 | 9. | .0841 | -.3714 | -3.7105 | -.4000 |
| 23 | 3 | 1 | 55. | .5140 | .5894 | -.0596 | .7297 |
| 23 | 4 | 0 | 9. | .0841 | -.2103 | -6.5531 | -.2151 |
| 23 | 5 | 0 | 14. | .1308 | -.0437 | -25.7064 | -.0437 |
| 24 | 1 | 0 | 3. | .0280 | -.3293 | -5.8008 | -.3488 |
| 24 | 2 | 0 | 10. | .0935 | -.0740 | -17.8431 | -.0742 |
| 24 | 3 | 1 | 65. | .6075 | .2126 | -1.2829 | .2176 |
| 24 | 4 | 0 | 19. | .1776 | .0083 | 111.2213 | .0083 |
| 24 | 5 | 0 | 10. | .0935 | -.3015 | -4.3773 | -.3162 |

TABLE 5. (CONTINUED)

| Item | Choice | Wt | NR | Difficulty | R | X50 | β |
|---|---|---|---|---|---|---|---|
| 25 | 1 | 1 | 32. | .2991 | -.2535 | -2.0791 | -.2621 |
| 25 | 2 | 0 | 11. | .1028 | -.2846 | -4.4476 | -.2969 |
| 25 | 3 | 0 | 48. | .4486 | .4040 | .3198 | .4417 |
| 25 | 4 | 0 | 4. | .0374 | -.0979 | -18.2095 | -.0983 |
| 25 | 5 | 0 | 12. | .1121 | -.0676 | -17.9779 | -.0677 |
| 26 | 1 | 0 | 10. | .0935 | -.3263 | -4.0443 | -.3452 |
| 26 | 2 | 1 | 70. | .6542 | .4587 | -.8648 | .5162 |
| 26 | 3 | 0 | 8. | .0748 | -.2500 | -5.7648 | -.2582 |
| 26 | 4 | 0 | 6. | .0561 | -.3812 | -4.1673 | -.4123 |
| 26 | 5 | 0 | 13. | .1215 | -.1799 | -6.4906 | -.1829 |
| 27 | 1 | 0 | 7. | .0654 | -.1801 | -8.3900 | -.1831 |
| 27 | 2 | 0 | 5. | .0467 | -.5122 | -3.2749 | -.5964 |
| 27 | 3 | 0 | 6. | .0561 | -.2528 | -6.2849 | -.2612 |
| 27 | 4 | 1 | 83. | .7757 | .5015 | -1.5111 | .5796 |
| 27 | 5 | 0 | 6. | .0561 | -.4301 | -3.6933 | -.4765 |
| 28 | 1 | 0 | 7. | .0654 | -.1909 | -7.9135 | -.1945 |
| 28 | 2 | 0 | 12. | .1121 | .0302 | 40.1835 | .0303 |
| 28 | 3 | 1 | 73. | .6822 | .2891 | -1.6397 | .3019 |
| 28 | 4 | 0 | 13. | .1215 | -.4058 | -2.8769 | -.4441 |
| 28 | 5 | 0 | 2. | .0187 | -.0571 | -36.4793 | -.0572 |
| 29 | 1 | 0 | 6. | .0561 | -.5280 | -3.0088 | -.6217 |
| 29 | 2 | 0 | 4. | .0374 | .0462 | 38.6055 | .0462 |
| 29 | 3 | 0 | 29. | .2710 | -.3498 | -1.7429 | -.3734 |
| 29 | 4 | 0 | 26. | .2430 | .3133 | 2.2241 | .3299 |
| 29 | 5 | 1 | 42. | .3925 | .1918 | 1.4221 | .1954 |
| 30 | 1 | 1 | 61. | .5701 | .5907 | -.2990 | .7321 |
| 30 | 2 | 0 | 16. | .1495 | -.3243 | -3.2026 | -.3428 |
| 30 | 3 | 0 | 8. | .0748 | -.3772 | -3.8208 | -.4073 |
| 30 | 4 | 0 | 8. | .0748 | -.7245 | -1.9891 | -1.0512 |
| 30 | 5 | 0 | 14. | .1308 | -.0046 | -241.4384 | -.0046 |
| 31 | 1 | 1 | 45. | .4206 | .2898 | .6916 | .3028 |
| 31 | 2 | 0 | 34. | .3178 | -.0159 | -29.8801 | -.0159 |
| 31 | 3 | 0 | 14. | .1308 | -.3103 | -3.6177 | -.3264 |
| 31 | 4 | 0 | 7. | .0654 | -.2126 | -7.1063 | -.2176 |
| 31 | 5 | 0 | 7. | .0654 | -.1150 | -13.1357 | -.1158 |
| 32 | 1 | 0 | 8. | .0748 | -.2353 | -6.1243 | -.2421 |
| 32 | 2 | 1 | 64. | .5981 | .5058 | -.4914 | .5863 |
| 32 | 3 | 0 | 20. | .1869 | -.1717 | -5.1802 | -.1743 |
| 32 | 4 | 0 | 11. | .1028 | -.5354 | -2.3643 | -.6338 |
| 32 | 5 | 0 | 4. | .0374 | -.2503 | -7.1180 | -.2586 |

TABLE 5. (CONTINUED)

| Item | Choice | Wt | NR | Difficulty | R | X50 | β |
|---|---|---|---|---|---|---|---|
| 33 | 1 | 0 | 20. | .1869 | -.1717 | -5.1802 | -.1743 |
| 33 | 2 | 0 | 8. | .0748 | .2060 | -6.9971 | -.2105 |
| 33 | 3 | 0 | 1. | .0093 | -.3269 | -7.1934 | -.3459 |
| 33 | 4 | 1 | 78. | .7290 | .2518 | -2.4213 | .2602 |
| 33 | 5 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 34 | 1 | 0 | 3. | .0280 | -.3938 | -4.8515 | -.4284 |
| 34 | 2 | 0 | 14. | .1308 | -.3623 | -3.0982 | -.3887 |
| 34 | 3 | 1 | 56. | .5234 | .4290 | -.1366 | .4749 |
| 34 | 4 | 0 | 7. | .0654 | -.2505 | -6.0299 | -.2588 |
| 34 | 5 | 0 | 27. | .2523 | -.1146 | -5.8218 | -.1154 |
| 35 | 1 | 0 | 1. | .0093 | -.5744 | -4.0940 | -.7017 |
| 35 | 2 | 0 | 4. | .0374 | -.3181 | -5.6015 | -.3355 |
| 35 | 3 | 1 | 77. | .7196 | .5058 | -1.1500 | .5864 |
| 35 | 4 | 0 | 13. | .1215 | -.2997 | -3.8956 | -.3141 |
| 35 | 5 | 0 | 12. | .1121 | -.3647 | -3.3318 | -.3917 |
| 36 | 1 | 1 | 77. | .7196 | .5571 | -1.0442 | .6709 |
| 36 | 2 | 0 | 9. | .0841 | -.4519 | -3.0491 | -.5066 |
| 36 | 3 | 0 | 3. | .0280 | -.8341 | -2.2903 | -1.5124 |
| 36 | 4 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 36 | 5 | 0 | 18. | .1682 | -.2556 | -3.7612 | -.2643 |
| 37 | 1 | 0 | 14. | .1308 | -.1802 | -6.2283 | -.1832 |
| 37 | 2 | 0 | 7. | .0654 | -.2722 | -5.5496 | -.2829 |
| 27 | 3 | 1 | 42. | .3925 | .6591 | .4138 | .8764 |
| 27 | 4 | 0 | 34. | .3178 | -.3569 | -1.3281 | -.3820 |
| 27 | 5 | 0 | 10. | .0935 | -.3181 | -4.1495 | -.3355 |
| 38 | 1 | 0 | 9. | .0841 | -.3579 | -3.8496 | -.3833 |
| 38 | 2 | 0 | 4. | .0374 | -.5638 | -3.1607 | -.6826 |
| 38 | 3 | 0 | 14. | .1308 | .1839 | 6.1028 | .1871 |
| 38 | 4 | 0 | 1. | .0093 | -.1894 | -12.4152 | -.1929 |
| 38 | 5 | 1 | 79. | .7383 | .2056 | -3.1037 | .2101 |
| 39 | 1 | 1 | 72. | .6729 | .3045 | -1.4708 | .3197 |
| 39 | 2 | 0 | 3. | .0280 | -.0716 | -26.6935 | -.0718 |
| 39 | 3 | 0 | 1. | .0093 | -.6019 | -3.9069 | -.7537 |
| 39 | 4 | 0 | 27. | .2523 | -.2466 | -2.7059 | -.2544 |
| 39 | 5 | 0 | 4. | .0374 | -.1402 | -12.7086 | -.1416 |
| 40 | 1 | 0 | 4. | .0374 | -.3774 | -4.7214 | -.4075 |
| 40 | 2 | 1 | 52. | .4860 | .3601 | .0976 | .3860 |
| 40 | 3 | 0 | 4. | .0374 | -.3351 | -5.3183 | -.3556 |
| 40 | 4 | 0 | 44. | .4112 | -.1830 | -1.2261 | -.1862 |
| 40 | 5 | 0 | 3. | .0280 | -.2219 | -8.6081 | -.2276 |

TABLE 5. (CONTINUED)

| Item | Choice | Wt | NR | Difficulty | R | X50 | β |
|---|---|---|---|---|---|---|---|
| 41 | 1 | 1 | 74. | .6916 | .6895 | -.7257 | .9519 |
| 41 | 2 | 0 | 29. | .2710 | -.7023 | -.8682 | -.9864 |
| 41 | 3 | 0 | 3. | .0280 | -.0823 | -23.2103 | -.0826 |
| 41 | 4 | 0 | 1. | .0093 | -.1894 | -12.4152 | -.1929 |
| 41 | 5 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 42 | 1 | 0 | 16. | .1495 | .2488 | 4.1738 | .2569 |
| 42 | 2 | 0 | 17. | .1589 | -.3226 | -3.0970 | -.3408 |
| 42 | 3 | 0 | 10. | .0935 | -.5042 | -2.6174 | -.5839 |
| 42 | 4 | 1 | 56. | .5234 | .3648 | -.1606 | .3918 |
| 42 | 5 | 0 | 8. | .0748 | -.2891 | -4.9845 | -.3020 |
| 43 | 1 | 0 | 21. | .1963 | -.3860 | -2.2153 | -.4184 |
| 43 | 2 | 0 | 4. | .0374 | -.3774 | -4.7214 | -.4075 |
| 43 | 3 | 1 | 55. | .5140 | .3105 | -.1132 | .3266 |
| 43 | 4 | 0 | 1. | .0093 | -.5744 | -4.0940 | -.7017 |
| 43 | 5 | 0 | 26. | .2430 | .0903 | 7.7141 | .0907 |
| 44 | 1 | 0 | 7. | .0654 | -.1367 | -11.0519 | -.1380 |
| 44 | 2 | 0 | 4. | .0374 | .0462 | 38.6055 | .0462 |
| 44 | 3 | 0 | 6. | .0561 | -.3629 | -4.3781 | -.3894 |
| 44 | 4 | 0 | 5. | .0467 | -.1304 | -12.8654 | -.1315 |
| 44 | 5 | 1 | 85. | .7944 | .2367 | -3.4712 | .2437 |
| 45 | 1 | 0 | 5. | .0467 | -.4627 | -3.6252 | -.5220 |
| 45 | 2 | 0 | 3. | .0280 | -.0716 | -26.6935 | -.0718 |
| 45 | 3 | 0 | 9. | .0000 | .0000 | .0000 | .0000 |
| 45 | 4 | 0 | 2. | .0187 | -.4500 | -4.6257 | -.5039 |
| 45 | 5 | 1 | 97. | .9065 | .4215 | -3.1313 | .4648 |
| 46 | 1 | 0 | 11. | .1028 | -.1148 | -11.0219 | -.1156 |
| 46 | 2 | 0 | 25. | .2336 | -.2350 | -3.0932 | -.2418 |
| 46 | 3 | 0 | 4. | .0374 | -.3266 | -5.4562 | -.3455 |
| 46 | 4 | 1 | 65. | .5981 | .3807 | -.6527 | .4117 |
| 46 | 5 | 0 | 2. | .0187 | -.1780 | -11.6965 | -.1809 |
| 47 | 1 | 0 | 33. | .3084 | -.1360 | -3.6789 | -.1373 |
| 47 | 2 | 1 | 45. | .4206 | .5301 | .3781 | .6252 |
| 47 | 3 | 0 | 10. | .0935 | -.4091 | -3.2263 | -.4483 |
| 47 | 4 | 0 | 7. | .0654 | -.1692 | -8.9275 | -.1717 |
| 47 | 5 | 0 | 12. | .1028 | -.2769 | -4.5715 | -.2881 |
| 48 | 1 | 0 | 26. | .2430 | .0727 | 9.5889 | .0729 |
| 48 | 2 | 0 | 26. | .2430 | .1168 | 5.9647 | .1176 |
| 48 | 3 | 0 | 20. | .1776 | -.0050 | -186.2958 | -.0050 |
| 48 | 4 | 1 | 9. | .0841 | .1790 | 7.6966 | .1820 |
| 48 | 5 | 0 | 26. | .2430 | -.2099 | -3.3195 | -.2147 |

TABLE 5. (CONTINUED)

| Item | Choice | Wt | NR | Difficulty | R | X50 | β |
|---|---|---|---|---|---|---|---|
| 49 | 1 | 0 | 12. | .1121 | .0520 | 23.3771 | .0521 |
| 49 | 2 | 0 | 6. | .0561 | -.5219 | -3.0440 | -.6118 |
| 49 | 3 | 0 | 5. | .0467 | -.3284 | -5.1084 | -.3476 |
| 49 | 4 | 0 | 13. | .1215 | -.1388 | -8.4118 | -.1402 |
| 49 | 5 | 1 | 71. | .6542 | .3501 | -1.1332 | .3737 |
| 50 | 1 | 0 | 22. | .1963 | -.1089 | -7.8492 | -.1096 |
| 50 | 2 | 0 | 7. | .0654 | -.4891 | -3.0890 | -.5607 |
| 50 | 3 | 1 | 55. | .5140 | .4179 | -.0841 | .4600 |
| 50 | 4 | 0 | 6. | .0561 | -.3323 | -4.7810 | -.3523 |
| 50 | 5 | 0 | 17. | .1589 | -.0687 | -14.5372 | -.0689 |
| 51 | 1 | 0 | 16. | .1495 | .2607 | 3.9836 | .2700 |
| 51 | 2 | 0 | 9. | .0841 | .2059 | 6.6929 | .2104 |
| 51 | 3 | 0 | 7. | .0654 | -.3210 | -4.7061 | -.3390 |
| 51 | 4 | 0 | 21. | .1963 | .0683 | 12.5234 | .0684 |
| 51 | 5 | 1 | 54. | .4953 | -.1265 | -.0926 | -.1275 |
| 52 | 1 | 1 | 98. | .9065 | .2684 | -4.9170 | .2786 |
| 52 | 2 | 0 | 2. | .0287 | -.0722 | -28.8408 | -.0724 |
| 52 | 3 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 52 | 4 | 0 | 3. | .0280 | .1862 | 10.2601 | .1895 |
| 52 | 5 | 0 | 4. | .0374 | -.4113 | -4.3324 | -.4512 |
| 53 | 1 | 0 | 6. | .0561 | -.0265 | -60.0258 | -.0265 |
| 53 | 2 | 0 | 25. | .2243 | -.2453 | -3.0889 | -.2530 |
| 53 | 3 | 0 | 1. | .0093 | -.5469 | -4.2998 | -.6553 |
| 53 | 4 | 0 | 24. | .2243 | -.2130 | -3.5574 | -.2180 |
| 53 | 5 | 0 | 51. | .4766 | .4367 | .1342 | .4854 |
| 54 | 1 | 0 | 14. | .1308 | -.5639 | -1.9906 | -.6827 |
| 54 | 2 | 0 | 8. | .0748 | -.2206 | -6.5317 | -.2262 |
| 54 | 3 | 1 | 48. | .4486 | .3813 | .3388 | .4125 |
| 54 | 4 | 0 | 8. | .0748 | -.2647 | -5.4451 | -.2745 |
| 54 | 5 | 0 | 29. | .2617 | .1765 | 3.6159 | .1793 |
| 55 | 1 | 0 | 9. | .0841 | .0761 | 18.1038 | .0763 |
| 55 | 2 | 1 | 72. | .6729 | .5496 | -.8150 | .6578 |
| 55 | 3 | 0 | 1. | .0093 | -.0519 | -45.2972 | -.0520 |
| 55 | 4 | 0 | 4. | .0374 | -.5638 | -3.1607 | -.6826 |
| 55 | 5 | 0 | 21. | .1869 | -.5317 | -1.6726 | -.6278 |
| 56 | 1 | 0 | 14. | .1308 | -.1932 | -5.8091 | -.1969 |
| 56 | 2 | 0 | 19. | .1776 | .1968 | 4.6973 | .2008 |
| 56 | 3 | 1 | 54. | .4953 | .2891 | .0405 | .3020 |
| 56 | 4 | 0 | 10. | .0935 | -.3346 | -3.9443 | -.3551 |
| 56 | 5 | 0 | 10. | .0935 | -.2974 | -4.4382 | -.3115 |

TABLE 5. (CONTINUED)

| Item | Choice | Wt | NR | Difficulty | R | X50 | β |
|---|---|---|---|---|---|---|---|
| 57 | 1 | 0 | 18. | .1682 | -.1923 | -4.9973 | -.1960 |
| 57 | 2 | 0 | 31. | .2897 | -.0778 | -7.1249 | -.0780 |
| 57 | 3 | 0 | 28. | .2523 | -.0454 | -14.7049 | -.0454 |
| 57 | 4 | 1 | 26. | .2430 | .4258 | 1.6361 | .4706 |
| 57 | 5 | 0 | 4. | .0374 | -.2927 | -6.0879 | -.3061 |
| 58 | 1 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 58 | 2 | 0 | 13. | .1215 | -.2518 | -4.6372 | -.2602 |
| 58 | 3 | 0 | 5. | .0467 | -.5476 | -3.0634 | -.6544 |
| 58 | 4 | 1 | 76. | .7009 | .5500 | 0.9584 | .6585 |
| 58 | 5 | 0 | 13. | .1215 | -.3305 | -3.5325 | -.3502 |
| 59 | 1 | 0 | 14. | .1308 | -.4696 | -2.3903 | -.5319 |
| 59 | 2 | 0 | 2. | .0187 | .0790 | 26.3643 | .0792 |
| 59 | 3 | 0 | 12. | .1121 | .0592 | 20.5168 | .0593 |
| 59 | 4 | 1 | 44. | .4112 | .4669 | .4806 | .5280 |
| 59 | 5 | 0 | 35. | .3178 | -.2154 | -2.2001 | -.2206 |
| 60 | 1 | 1 | 67. | .6262 | .4459 | -.7215 | .4982 |
| 60 | 2 | 0 | 16. | .1495 | -.1877 | -5.5334 | -.1911 |
| 60 | 3 | 0 | 7. | .0561 | -.4791 | -3.3161 | -.5458 |
| 60 | 4 | 0 | 12. | .1131 | -.0567 | -21.4232 | -.0568 |
| 60 | 5 | 0 | 5. | .0467 | -.4132 | -4.0594 | -.4538 |
| 61 | 1 | 0 | 33. | .2991 | -.1739 | -3.0305 | -.1766 |
| 61 | 2 | 0 | 22. | .2056 | -.4212 | -1.9510 | -.4644 |
| 61 | 3 | 0 | 3. | .0280 | -.4367 | -4.3743 | -.4855 |
| 61 | 4 | 1 | 48. | .4486 | .6118 | .2112 | .7735 |
| 61 | 5 | 0 | 1. | .0093 | -.5469 | -4.2998 | -.6533 |
| 62 | 1 | 1 | 40. | .3738 | .2981 | 1.0791 | .3124 |
| 62 | 2 | 0 | 23. | .2150 | -.0979 | -8.0590 | -.0984 |
| 62 | 3 | 0 | 33. | .3084 | -.0379 | -13.2101 | -.0379 |
| 62 | 4 | 0 | 8. | .0748 | -.3234 | -4.4567 | -.3417 |
| 62 | 5 | 0 | 3. | .0187 | -.1175 | -17.7135 | -.1183 |
| 63 | 1 | 0 | 19. | .1776 | .0163 | 56.7975 | .0163 |
| 63 | 2 | 1 | 10. | .0935 | -.0822 | -16.0479 | -.0825 |
| 63 | 3 | 0 | 1. | .0093 | -.3544 | -6.6353 | -.3790 |
| 63 | 4 | 0 | 7. | .0654 | -.1421 | -10.6303 | -.1436 |
| 63 | 5 | 0 | 70. | .6449 | .1517 | -2.4495 | .1534 |
| 64 | 1 | 0 | 6. | .0561 | .2732 | 5.8142 | .2840 |
| 64 | 2 | 1 | 31. | .2897 | .2554 | 2.1702 | .2641 |
| 64 | 3 | 0 | 18. | .1682 | -.3985 | -2.4122 | -.4345 |
| 64 | 4 | 0 | 42. | .3925 | .1307 | 2.0871 | .1318 |
| 64 | 5 | 0 | 10. | .0841 | -.3132 | -4.3996 | -.3298 |

TABLE 5. (CONTINUED)

| Item | Choice | Wt | NR | Difficulty | R | X50 | β |
|---|---|---|---|---|---|---|---|
| 65 | 1 | 0 | 3. | .0280 | -.6301 | -3.0321 | -.8114 |
| 65 | 2 | 1 | 29. | .2710 | .5115 | 1.1921 | .5952 |
| 65 | 3 | 0 | 49. | .4579 | -.1698 | -.6220 | -.1723 |
| 65 | 4 | 0 | 24. | .2150 | -.1476 | -5.3477 | -.1492 |
| 65 | 5 | 0 | 2. | .0187 | .0336 | 61.9228 | .0336 |
| 66 | 1 | 0 | 8. | .0748 | -.4848 | -2.9726 | -.5543 |
| 66 | 2 | 0 | 56. | .5234 | .1184 | -.4947 | .1193 |
| 66 | 3 | 0 | 16. | .1494 | -.0184 | -56.3588 | -.0184 |
| 66 | 4 | 1 | 19. | .1776 | .4013 | 2.3041 | .4381 |
| 66 | 5 | 0 | 8. | .0654 | -.4620 | -3.2702 | -.5209 |
| 67 | 1 | 0 | 4. | .0374 | -.2758 | -6.4620 | -.2869 |
| 67 | 2 | 1 | 89. | .8224 | .5785 | -1.5983 | .7093 |
| 67 | 3 | 0 | 7. | .0654 | -.4295 | -3.5179 | -.4755 |
| 67 | 4 | 0 | 4. | .0374 | -.2080 | -8.5676 | -.2126 |
| 67 | 5 | 0 | 3. | .0280 | -.5656 | -3.3775 | -.6859 |
| 68 | 1 | 0 | 6. | .0561 | -.4974 | -3.1937 | -.5734 |
| 68 | 2 | 1 | 69. | .6449 | .5858 | -.6341 | .7228 |
| 68 | 3 | 0 | 15. | .1308 | -.4176 | -2.6881 | -.4595 |
| 68 | 4 | 0 | 6. | .0561 | -.2100 | -7.5666 | -.2147 |
| 68 | 5 | 0 | 11. | .1028 | -.1650 | -7.6715 | -.1673 |
| 69 | 1 | 0 | 20. | .1869 | -.3028 | -2.9367 | -.3178 |
| 69 | 2 | 0 | 5. | .0467 | -.5829 | -2.8776 | -.7174 |
| 69 | 3 | 0 | 15. | .1402 | -.3173 | -3.4022 | -.3346 |
| 69 | 4 | 1 | 51. | .4766 | .5390 | .1087 | .6399 |
| 69 | 5 | 0 | 16. | .1402 | .0641 | 16.8309 | .0643 |
| 70 | 1 | 0 | 16. | .1495 | .0558 | 18.6088 | .0559 |
| 70 | 2 | 1 | 53. | .4860 | .3133 | .1122 | .3300 |
| 70 | 3 | 0 | 21. | .1963 | -.2188 | -3.9087 | -.2242 |
| 70 | 4 | 0 | 4. | .0374 | -.4113 | -4.3324 | -.4512 |
| 70 | 5 | 0 | 13. | .1215 | -.1183 | -9.8729 | -.1191 |
| 71 | 1 | 1 | 45. | .4206 | .4577 | .4380 | .5148 |
| 71 | 2 | 0 | 50. | .4673 | -.1623 | -.5058 | -.1645 |
| 71 | 3 | 0 | 6. | .0467 | -.2930 | -5.7247 | -.3065 |
| 71 | 4 | 0 | 3. | .0280 | -.7697 | -2.4821 | -1.2057 |
| 71 | 5 | 0 | 3. | .0280 | -.2542 | -7.5168 | -.2628 |
| 72 | 1 | 1 | 26. | .2430 | .4943 | 1.4096 | .5686 |
| 72 | 2 | 0 | 9. | .0841 | -.5325 | -2.5879 | -.6290 |
| 72 | 3 | 0 | 18. | .1589 | -.0944 | -10.5837 | -.0948 |
| 72 | 4 | 0 | 3. | .0280 | -.1253 | -15.2504 | -.1263 |
| 72 | 5 | 0 | 51. | .4766 | -.0543 | -1.0800 | -.0543 |

TABLE 5. (CONTINUED)

| Item | Choice | Wt | NR | Difficulty | R | X50 | β |
|---|---|---|---|---|---|---|---|
| 73 | 1 | 0 | 2. | .0187 | -.6011 | -3.4628 | -.7522 |
| 73 | 2 | 0 | 4. | .0280 | -.0823 | -23.2103 | -.0826 |
| 73 | 3 | 1 | 77. | .7196 | .5017 | -1.1594 | .5800 |
| 73 | 4 | 0 | 8. | .0748 | -.3234 | -4.4567 | -.3417 |
| 73 | 5 | 0 | 16. | .1495 | -.3035 | -3.4219 | -.3185 |
| 74 | 1 | 0 | 5. | .0467 | -.5900 | -2.8431 | -.7307 |
| 74 | 2 | 0 | 3. | .0280 | -.6945 | -2.7508 | -.9653 |
| 74 | 3 | 0 | 12. | .1121 | .1353 | 8.9799 | .1366 |
| 74 | 4 | 0 | 22. | .1963 | -.3760 | -2.2741 | -.4058 |
| 74 | 5 | 1 | 65. | .6075 | .5217 | -.5228 | .6116 |
| 75 | 1 | 0 | 20. | .1869 | .1729 | 5.1428 | .1756 |
| 75 | 2 | 0 | 9. | .0841 | -.2729 | -5.0489 | -.2837 |
| 75 | 3 | 1 | 35. | .3271 | .2717 | 1.6486 | .2823 |
| 75 | 4 | 0 | 9. | .0841 | .0045 | 305.0824 | .0045 |
| 75 | 5 | 0 | 34. | .3084 | -.2361 | -2.1192 | -.2430 |
| 76 | 1 | 1 | 72. | .6729 | .7793 | -.5748 | 1.2437 |
| 76 | 2 | 0 | 4. | .0374 | -.5129 | -3.4738 | -.5975 |
| 76 | 3 | 0 | 16. | .1495 | -.4549 | -2.2828 | -.5108 |
| 76 | 4 | 0 | 4. | .0280 | -.5549 | -3.4429 | -.6670 |
| 76 | 5 | 0 | 11. | .1028 | -.4351 | -2.9094 | -.4832 |
| 77 | 1 | 0 | 10. | .0935 | -.2725 | -4.8424 | -.2833 |
| 77 | 2 | 1 | 74. | .6822 | .5409 | -.8762 | .6432 |
| 77 | 3 | 0 | 4. | .0374 | -.4198 | -4.2450 | -.4625 |
| 77 | 4 | 0 | 12. | .1121 | -.2162 | -5.6218 | -.2214 |
| 77 | 5 | 0 | 7. | .0654 | -.4078 | -3.7050 | -.4466 |
| 78 | 1 | 1 | 53. | .4953 | .1281 | .0915 | .1291 |
| 78 | 2 | 0 | 3. | .0280 | .1540 | 12.4071 | .1558 |
| 78 | 3 | 0 | 5. | .0374 | -.3096 | -5.7548 | -.3256 |
| 78 | 4 | 0 | 17. | .1589 | .2707 | 3.6905 | .2812 |
| 78 | 5 | 0 | 29. | .2710 | -.2456 | -2.4830 | -.2533 |
| 79 | 1 | 0 | 30. | .2804 | .1382 | 4.2105 | .1395 |
| 79 | 2 | 1 | 45. | .4112 | .3710 | .6048 | .3996 |
| 79 | 3 | 0 | 13. | .1215 | -.2689 | -4.3420 | -.2792 |
| 79 | 4 | 0 | 15. | .1402 | -.3049 | -3.5406 | -.3201 |
| 79 | 5 | 0 | 4. | .0374 | -.5977 | -2.9815 | -.7454 |
| 80 | 1 | 0 | 9. | .0841 | -.2953 | -4.6663 | -.3091 |
| 80 | 2 | 0 | 4. | .0374 | -.4028 | -4.4235 | -.4401 |
| 80 | 3 | 0 | 6. | .0561 | -.5463 | -2.9077 | -.6523 |
| 80 | 4 | 1 | 41. | .3832 | .6001 | .4951 | .7503 |
| 80 | 5 | 0 | 47. | .4299 | -.1756 | -1.0057 | -.1784 |

TABLE 5. (CONTINUED)

| Item | Choice | Wt | NR | Difficulty | R | X50 | β |
|---|---|---|---|---|---|---|---|
| 81 | 1 | 1 | 44. | .4112 | .4794 | .4682 | .5462 |
| 81 | 2 | 0 | 15. | .1308 | -.3850 | -2.9151 | -.4172 |
| 81 | 3 | 0 | 5. | .0467 | -.2577 | -6.5103 | -.2667 |
| 81 | 4 | 0 | 6. | .0561 | -.6748 | -2.3543 | -.9143 |
| 81 | 5 | 0 | 37. | .3458 | .0452 | 8.7681 | .0453 |
| 82 | 1 | 0 | 17. | .1589 | -.0858 | -11.6388 | -.0862 |
| 82 | 2 | 0 | 8. | .0748 | -.0935 | -15.4217 | -.0939 |
| 82 | 3 | 0 | 8. | .0748 | -.4555 | -3.1642 | -.5116 |
| 82 | 4 | 1 | 62. | .5794 | .4469 | -.4485 | .4996 |
| 82 | 5 | 0 | 12. | .1028 | -.3155 | -4.0124 | -.3324 |
| 83 | 1 | 0 | 1. | .0093 | -.6294 | -3.7362 | -.8100 |
| 83 | 2 | 0 | 3. | .0280 | .1218 | 15.6904 | .1227 |
| 83 | 3 | 0 | 17. | .1589 | -.5508 | -1.8139 | -.6599 |
| 83 | 4 | 0 | 10. | .0935 | -.4794 | -2.7530 | -.5436 |
| 83 | 5 | 1 | 76. | .7009 | .6952 | -.7581 | .9673 |
| 84 | 1 | 0 | 6. | .0561 | -.2711 | -5.8596 | -.2817 |
| 84 | 2 | 0 | 11. | .1028 | -.4852 | -2.6087 | -.5549 |
| 84 | 3 | 1 | 80. | .7383 | .6429 | -.9926 | .8394 |
| 84 | 4 | 0 | 2. | .0187 | -.2989 | -6.9649 | -.3132 |
| 84 | 5 | 0 | 8. | .0748 | -.4114 | -3.5028 | -.4514 |
| 85 | 1 | 0 | 8. | .0748 | -.6022 | -2.3931 | -.7544 |
| 85 | 2 | 0 | 10. | .0935 | -.3263 | -4.0443 | -.3452 |
| 85 | 3 | 1 | 76. | .7009 | .5997 | -.8789 | .7495 |
| 85 | 4 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 85 | 5 | 0 | 13. | .1215 | -.2415 | -4.8344 | -.2489 |
| 86 | 1 | 0 | 15. | .1402 | -.5158 | -2.0930 | -.6020 |
| 86 | 2 | 0 | 3. | .0280 | -.6730 | -2.8385 | -.9100 |
| 86 | 3 | 0 | 10. | .0935 | -.3760 | -3.5103 | -.4057 |
| 86 | 4 | 1 | 75. | .6916 | .7169 | -.6979 | 1.0284 |
| 86 | 5 | 0 | 4. | .0374 | -.1402 | -12.7086 | -.1416 |
| 87 | 1 | 0 | 12. | .1121 | .1317 | 9.2270 | .1329 |
| 87 | 2 | 0 | 5. | .0467 | -.0385 | -43.6142 | -.0385 |
| 87 | 3 | 1 | 32. | .2991 | .3733 | 1.4121 | .4023 |
| 87 | 4 | 0 | 42. | .3925 | -.4265 | -.6395 | -.4715 |
| 87 | 5 | 0 | 16. | .1402 | .1479 | 7.3004 | .1495 |
| 88 | 1 | 0 | 5. | .0467 | -.4839 | -3.4663 | -.5530 |
| 88 | 2 | 0 | 12. | .1028 | -.2036 | -6.2176 | -.2079 |
| 88 | 3 | 0 | 12. | .1121 | -.6365 | -1.9002 | -.8252 |
| 88 | 4 | 1 | 72. | .6729 | .6913 | -.6480 | .9566 |
| 88 | 5 | 0 | 6. | .0561 | -.2161 | -7.3524 | -.2213 |

TABLE 5. (CONTINUED)

| Item | Choice | Wt | NR | Difficulty | R | X50 | β |
|---|---|---|---|---|---|---|---|
| 89 | 1 | 1 | 60. | .5514 | .4760 | -.2714 | .5413 |
| 89 | 2 | 0 | 23. | .2150 | -.1783 | -4.4260 | -.1813 |
| 89 | 3 | 0 | 10. | .0935 | -.4008 | -3.2929 | -.4375 |
| 89 | 4 | 0 | 9. | .0841 | -.1789 | -7.7002 | -.1819 |
| 90 | 1 | 0 | 16. | .1402 | -.1964 | -5.4977 | -.2003 |
| 90 | 2 | 0 | 16. | .1495 | -.6301 | -1.6481 | -.8114 |
| 90 | 3 | 1 | 35. | .3271 | .5014 | .8933 | .5796 |
| 90 | 4 | 0 | 25. | .2336 | .2995 | 2.4269 | .3139 |
| 90 | 5 | 0 | 15. | .1402 | -.2801 | -3.8542 | -.2918 |

APPENDIX B

TABLES FOR SCHOOL B - CHEMISTRY CLASSES

Table 1.

Reliabilities for Subtests and Total Test
for School B--Chemistry Classes
(Hoyt ANOVA for Internal Consistency)

| Reliability | Subtest a | Subtest b | Subtest c | Total Test |
|---|---|---|---|---|
| Pretest | .454 | .530 | .610 | .744 |
| Posttest | .601 | .502 | .560 | .778 |

Table 2.

Number and Proportion of Students Answering
Each Item Correctly on Pretest and Posttest for
Concepts Related to Science and Scientists

School B--Chemistry Classes (N = 76)

| Question | Number and Proportion | Question | Number and Proportion |
|---|---|---|---|
| 1 Pre | 43 (.56) | 46 Pre | 52 (.68) |
| 1 Post | 60 (.78) | 46 Post | 56 (.73) |
| 2 Pre | 62 (.81) | 47 Pre | 19 (.25) |
| 2 Post | 64 (.84) | 47 Post | 48 (.63) |
| 3 Pre | 59 (.77) | 48 Pre | 31 (.41) |
| 3 Post | 61 (.80) | 48 Post | 45 (.59) |
| 4 Pre | 57 (.75) | 49 Pre | 20 (.26) |
| 4 Post | 71 (.93) | 49 Post | 66 (.86) |
| 5 Pre | 45 (.59) | 50 Pre | 19 (.25) |
| 5 Post | 68 (.89) | 50 Post | 57 (.75) |
| 6 Pre | 13 (.17) | 51 Pre | 46 (.60) |
| 6 Post | 38 (.50) | 51 Post | 52 (.68) |
| 7 Pre | 34 (.44) | 52 Pre | 72 (.94) |
| 7 Post | 58 (.76) | 52 Post | 76 (1.00) |
| 8 Pre | 4 (.05) | 53 Pre | 38 (.50) |
| 8 Post | 45 (.59) | 53 Post | 49 (.64) |
| 9 Pre | 41 (.53) | 54 Pre | 33 (.43) |
| 9 Post | 53 (.69) | 54 Post | 47 (.61) |
| 10 Pre | 71 (.93) | 55 Pre | 52 (.58) |
| 10 Post | 75 (.98) | 55 Post | 67 (.88) |
| 11 Pre | 32 (.42) | 56 Pre | 49 (.64) |
| 11 Post | 75 (.39)** | 56 Post | 55 (.72) |
| 12 Pre | 22 (.29) | 57 Pre | 14 (.18) |
| 12 Post | 48 (.63) | 57 Post | 39 (.51) |

*No Change
**Decrease

Table 2. (continued)

| Question | Number and Proportion | Question | Number and Proportion |
|---|---|---|---|
| 13 Pre | 28 (.37) | 58 Pre | 63 (.83) |
| 13 Post | 34 (.44) | 58 Post | 70 (.92) |
| 14 Pre | 53 (.69) | 59 Pre | 39 (.51) |
| 14 Post | 61 (.80) | 59 Post | 48 (.63) |
| 15 Pre | 22 (.28) | 60 Pre | 36 (.47) |
| 15 Post | 47 (.61) | 60 Post | 68 (.89) |

Table 3.

Number and Proportion of Students Answering
Each Item Correctly on Pretest and Posttest for
Concepts Related to Science and Society

School B--Chemistry Classes (N = 76)

| Question | Number and Proportion | Question | Number and Proportion |
|---|---|---|---|
| 16 Pre | 15 (.19) | 61 Pre | 32 (.42) |
| 16 Post | 49 (.64) | 61 Post | 59 (.77) |
| 17 Pre | 9 (.11) | 62 Pre | 22 (.28) |
| 17 Post | 60 (.78) | 62 Post | 55 (.72) |
| 18 Pre | 11 (.14) | 63 Pre | 3 (.03) |
| 18 Post | 26 (.34) | 63 Post | 8 (.10) |
| 19 Pre | 25 (.32) | 64 Pre | 10 (.13) |
| 19 Post | 57 (.75) | 64 Post | 26 (.34) |
| 20 Pre | 37 (.48) | 65 Pre | 27 (.35) |
| 20 Post | 62 (.81) | 65 Post | 60 (.78) |
| 21 Pre | 72 (.94) | 66 Pre | 19 (.25) |
| 21 Post | 70 (.92)** | 66 Post | 33 (.43) |
| 22 Pre | 49 (.64) | 67 Pre | 71 (.93) |
| 22 Post | 67 (.88) | 67 Post | 72 (.94) |
| 23 Pre | 45 (.59) | 68 Pre | 35 (.46) |
| 23 Post | 55 (.72) | 68 Post | 70 (.92) |
| 24 Pre | 35 (.47) | 69 Pre | 36 (.47) |
| 24 Post | 61 (.80) | 69 Post | 54 (.71) |

*No Change
**Decrease

Table 3. (continued)

| Question | Number and Proportion | Question | Number and Proportion |
|---|---|---|---|
| 25 Pre | 15 (.19) | 70 Pre | 20 (.26) |
| 25 Post | 27 (.35) | 70 Post | 37 (.48) |
| 26 Pre | 54 (.71) | 71 Pre | 24 (.31) |
| 26 Post | 70 (.92) | 71 Post | 57 (.75) |
| 27 Pre | 47 (.61) | 72 Pre | 23 (.30) |
| 27 Post | 67 (.88) | 72 Post | 39 (.51) |
| 28 Pre | 14 (.18) | 73 Pre | 59 (.77) |
| 28 Post | 75 (.98) | 73 Post | 67 (.88) |
| 29 Pre | 35 (.46) | 74 Pre | 46 (.60) |
| 29 Post | 22 (.29)** | 74 Post | 55 (.72) |
| 30 Pre | 48 (.63) | 75 Pre | 19 (.25) |
| 30 Post | 56 (.73) | 75 Post | 44 (.57) |

*No Change
**Decrease

Table 4.

Number and Proportion of Students Answering
Each Item Correctly on Pretest and Posttest for
Concepts Related to Atoms and Atomic Energy

School B--Chemistry Classes (N = 76)

| Question | Number and Proportion | Question | Number and Proportion |
|---|---|---|---|
| 31 Pre | 15 (.19) | 76 Pre | 49 (.64) |
| 31 Post | 54 (.71) | 76 Post | 68 (.89) |
| 32 Pre | 30 (.39) | 77 Post | 49 (.64) |
| 32 Post | 66 (.86) | 77 Post | 68 (.89) |
| 33 Pre | 51 (.67) | 78 Pre | 22 (.28) |
| 33 Post | 59 (.77) | 78 Post | 48 (.63) |
| 34 Pre | 39 (.39) | 79 Pre | 18 (.23) |
| 34 Post | 43 (.56) | 79 Post | 41 (.53) |
| 35 Pre | 52 (.68) | 80 Pre | 34 (.44) |
| 35 Post | 61 (.80) | 80 Post | 55 (.72) |
| 36 Pre | 42 (.55) | 81 Pre | 33 (.43) |
| 36 Post | 72 (.94) | 81 Post | 56 (.73) |
| 37 Pre | 18 (.23) | 82 Pre | 43 (.56) |
| 37 Post | 33 (.43) | 82 Post | 54 (.71) |
| 38 Pre | 49 (.64) | 83 Pre | 35 (.46) |
| 38 Post | 59 (.77) | 83 Post | 70 (.92) |
| 39 Pre | 52 (.68) | 84 Pre | 43 (.56) |
| 39 Post | 50 (.65)** | 84 Post | 66 (.86) |
| 40 Pre | 17 (.22) | 85 Post | 31 (.40) |
| 40 Post | 34 (.44) | 85 Post | 75 (.98) |
| 41 Pre | 46 (.60) | 86 Pre | 63 (.82) |
| 41 Post | 67 (.88) | 86 Post | 69 (.90) |

*No Change
**Decrease

Table 4. (continued)

| Question | Number and Proportion | Question | Number and Proportion |
|---|---|---|---|
| 42 Pre | 34 (.44) | 87 Pre | 17 (.22) |
| 42 Post | 41 (.53) | 87 Post | 48 (.63) |
| 43 Pre | 25 (.32) | 88 Pre | 38 (.50) |
| 43 Post | 61 (.80) | 88 Post | 72 (.94) |
| 44 Pre | 61 (.80) | 89 Pre | 36 (.47) |
| 44 Post | 68 (.89) | 89 Post | 45 (.59) |
| 45 Pre | 66 (.86) | 90 Pre | 12 (.16) |
| 45 Post | 73 (.96) | 90 Post | 24 (.31) |

TABLE 5. ITEM STATISTICS OF TOTAL TEST FOR SCHOOL B - CHEMISTRY CLASSES (POSTTEST)

| Item | Choice | Wt | NR | Difficulty | R | X50 | β |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 6. | .0789 | -.2426 | -5.8222 | -.2500 |
| 1 | 2 | 0 | 4. | .0526 | -.0712 | -22.7482 | -.0714 |
| 1 | 3 | 0 | 3. | .0395 | -.1904 | -9.2252 | -.1940 |
| 1 | 4 | 0 | 3. | .0395 | -.5693 | -3.0858 | -.6925 |
| 1 | 5 | 1 | 60. | .7895 | .3746 | -2.1479 | .4040 |
| 2 | 1 | 0 | 1. | .0132 | -.2236 | -9.9334 | -.2295 |
| 2 | 2 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 2 | 3 | 1 | 64. | .8421 | .1822 | -5.5062 | .1853 |
| 2 | 4 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 2 | 5 | 0 | 11. | .1447 | -.1598 | -6.6283 | -.1619 |
| 3 | 1 | 0 | 3. | .0395 | -.3799 | -4.6247 | -.4107 |
| 3 | 2 | 0 | 6. | .0789 | -.5937 | -2.3787 | -.7378 |
| 3 | 3 | 1 | 61. | .8026 | .5016 | -1.6967 | .5798 |
| 3 | 4 | 0 | 2. | .0263 | .0432 | 44.8699 | .0432 |
| 3 | 5 | 0 | 4. | .0526 | -.2065 | -7.8442 | -.2111 |
| 4 | 1 | 0 | 2. | .0263 | -.3539 | -5.4763 | -.3784 |
| 4 | 2 | 0 | 2. | .0263 | -.7245 | -2.6749 | -1.0510 |
| 4 | 3 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 4 | 4 | 1 | 71. | .9342 | .5227 | -2.8850 | .6131 |
| 4 | 5 | 0 | 1. | .0132 | -.0327 | -68.0057 | -.0327 |
| 5 | 1 | 0 | 5. | .0658 | -.5479 | -2.7521 | -.6550 |
| 5 | 2 | 1 | 68. | .8947 | .4475 | -2.7982 | .5004 |
| 5 | 3 | 0 | 1. | .0132 | -.0327 | -68.0057 | -.0327 |
| 5 | 4 | 0 | 2. | .0263 | -.1686 | -11.4956 | -.1710 |
| 5 | 5 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 6 | 1 | 0 | 1. | .0132 | -.4624 | -4.8047 | -.5214 |
| 6 | 2 | 1 | 38. | .5000 | .4291 | .0000 | .4751 |
| 6 | 3 | 0 | 10. | .1316 | -.1199 | -9.3295 | -.1208 |
| 6 | 4 | 0 | 1. | .0132 | -.0804 | -27.6273 | -.0807 |
| 6 | 5 | 0 | 26. | .3421 | -.3465 | -1.1739 | -.3693 |
| 7 | 1 | 0 | 11. | .1447 | -.2591 | -4.0878 | -.2683 |
| 7 | 2 | 0 | 3. | .0395 | -.2283 | -7.6944 | -.2345 |
| 7 | 3 | 0 | 1. | .0132 | -.2236 | -9.9334 | -.2295 |
| 7 | 4 | 0 | 3. | .0395 | -.0010 | -1762.0211 | -.0010 |
| 7 | 5 | 1 | 58. | .7632 | .2790 | -2.5682 | .2905 |
| 8 | 1 | 0 | 12. | .1579 | .2396 | 4.1863 | .2468 |
| 8 | 2 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 8 | 3 | 0 | 16. | .2105 | -.4194 | -1.9186 | -.4619 |
| 8 | 4 | 1 | 45. | .5921 | .1673 | -1.3928 | .1696 |
| 8 | 5 | 0 | 3. | .0395 | -.0199 | -88.1008 | -.0199 |

TABLE 5. (CONTINUED)

| Item | Choice | Wt | NR | Difficulty | R | X50 | β |
|---|---|---|---|---|---|---|---|
| 9 | 1 | 0 | 19. | .2500 | -.3405 | -1.9808 | -.3621 |
| 9 | 2 | 0 | 2. | .0263 | -.0362 | -53.4988 | -.0362 |
| 9 | 3 | 0 | 2. | .0263 | .2020 | 9.5929 | .2063 |
| 9 | 4 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 9 | 5 | 1 | 53. | .6974 | .2810 | -1.8393 | .2928 |
| 10 | 1 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 10 | 2 | 1 | 75. | .9868 | -.1106 | 20.0926 | -.1112 |
| 10 | 3 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 10 | 4 | 0 | 1. | .0132 | .1106 | 20.0926 | .1112 |
| 10 | 5 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 11 | 1 | 0 | 27. | .3553 | .0066 | 56.0702 | .0066 |
| 11 | 2 | 0 | 3. | .0395 | .2074 | 8.4712 | .2120 |
| 11 | 3 | 1 | 30. | .3947 | .1153 | 2.3166 | .1160 |
| 11 | 4 | 0 | 5. | .0658 | -.4848 | -3.1103 | -.5543 |
| 11 | 5 | 0 | 11. | .1447 | -.0108 | -97.8252 | -.0108 |
| 12 | 1 | 0 | 4. | .0526 | -.0261 | -62.0405 | -.0261 |
| 12 | 2 | 0 | 14. | .1842 | -.4646 | -1.9361 | -.5246 |
| 12 | 3 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 12 | 4 | 0 | 10. | .1316 | -.1578 | -7.0913 | -.1598 |
| 12 | 5 | 1 | 48. | .6316 | .4247 | -.7912 | .4691 |
| 13 | 1 | 1 | 34. | .4474 | .3501 | .3779 | .3738 |
| 13 | 2 | 0 | 16. | .2105 | -.3019 | -2.6655 | -.3166 |
| 13 | 3 | 0 | 3. | .0395 | -.0010 | -1762.0211 | -.0010 |
| 13 | 4 | 0 | 3. | .0395 | -.1336 | -13.1494 | -.1348 |
| 13 | 5 | 0 | 20. | .2632 | -.1221 | -5.1877 | -.1231 |
| 14 | 1 | 0 | 1. | .0231 | -.0327 | -68.0057 | -.0327 |
| 14 | 2 | 0 | 10. | .1316 | -.3168 | -3.5323 | -.3340 |
| 14 | 3 | 1 | 61. | .8026 | .3272 | -2.6013 | .3462 |
| 14 | 4 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 14 | 5 | 0 | 4. | .0526 | -.2065 | -7.8442 | -.2111 |
| 15 | 1 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 15 | 2 | 0 | 11. | .1447 | -.4365 | -2.4268 | -.4851 |
| 15 | 3 | 0 | 4. | .0526 | -.2666 | -6.0752 | -.2767 |
| 15 | 4 | 1 | 47. | .6184 | .4696 | -.6418 | .5318 |
| 15 | 5 | 0 | 14. | .1842 | -.1916 | -4.6951 | -.1952 |
| 16 | 1 | 0 | 5. | .0658 | -.2072 | -7.2773 | -.2118 |
| 16 | 2 | 0 | 3. | .0395 | -.1336 | -13.1494 | -.1348 |
| 16 | 3 | 0 | 5. | .0658 | -.0305 | -49.3588 | -.0306 |
| 16 | 4 | 0 | 14. | .1842 | -.4221 | -2.1309 | -.4656 |
| 16 | 5 | 1 | 49. | .6447 | .4141 | -.8964 | .4549 |

TABLE 5. (CONTINUED)

| Item | Choice | Wt | NR | Difficulty | R | X50 | β |
|---|---|---|---|---|---|---|---|
| 17 | 1 | 0 | 5. | .0658 | -.1694 | -8.9039 | -.1718 |
| 17 | 2 | 0 | 9. | .1184 | -.2050 | -5.7699 | -.2095 |
| 17 | 3 | 0 | 1. | .0132 | -.5578 | -3.9823 | -.6721 |
| 17 | 4 | 1 | 60. | .7895 | .3746 | -2.1479 | .4040 |
| 17 | 5 | 0 | 1. | .0132 | -.7966 | -2.7889 | -1.3176 |
| 18 | 1 | 1 | 26. | .3421 | .1284 | 3.1665 | .1295 |
| 18 | 2 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 18 | 3 | 0 | 13. | .1711 | .3757 | 2.5285 | .4054 |
| 18 | 4 | 0 | 15. | .1974 | -.1120 | -7.5979 | -.1127 |
| 18 | 5 | 0 | 22. | .2895 | -.3261 | -1.7019 | -.3449 |
| 19 | 1 | 1 | 57. | .7500 | .4015 | -1.6800 | .4384 |
| 19 | 2 | 0 | 11. | .1447 | -.1527 | -6.9363 | -.1545 |
| 19 | 3 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 19 | 4 | 0 | 7. | .0921 | -.3694 | -3.5945 | -.3976 |
| 19 | 5 | 0 | 1. | .0132 | -.9398 | -2.3638 | -2.7501 |
| 20 | 1 | 0 | 6. | .0789 | -.1877 | -7.5240 | -.1911 |
| 20 | 2 | 1 | 62. | .8158 | .5495 | -1.6369 | .6577 |
| 20 | 3 | 0 | 3. | .0395 | -.4557 | -3.8556 | -.5119 |
| 20 | 4 | 0 | 4. | .0526 | -.6575 | -2.4637 | -.8726 |
| 20 | 5 | 0 | 1. | .0132 | -.2714 | -8.1859 | -.2820 |
| 21 | 1 | 0 | 3. | .0395 | -.2852 | -6.1609 | -.2975 |
| 21 | 2 | 0 | 2. | .0263 | .0697 | 27.8193 | .0698 |
| 21 | 3 | 0 | 1. | .0132 | -.2236 | -9.9334 | -.2295 |
| 21 | 4 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 21 | 5 | 1 | 70. | .9211 | .1877 | -7.5240 | .1911 |
| 22 | 1 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 22 | 2 | 1 | 67. | .8816 | .4902 | -2.4129 | .5625 |
| 22 | 3 | 0 | 1. | .0132 | -.4624 | -4.8047 | -.5214 |
| 22 | 4 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 22 | 5 | 0 | 8. | .1053 | -.4475 | -2.7982 | -.5004 |
| 23 | 1 | 0 | 10. | .1316 | -.4758 | -2.3519 | -.5409 |
| 23 | 2 | 0 | 4. | .0526 | -.1464 | -11.0667 | -.1480 |
| 23 | 3 | 1 | 55. | .7237 | .4847 | -1.2253 | .5541 |
| 23 | 4 | 0 | 6. | .0789 | -.3194 | -4.4219 | -.3370 |
| 23 | 5 | 0 | 1. | .0132 | .0628 | 35.3629 | .0629 |
| 24 | 1 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 24 | 2 | 0 | 4. | .0526 | .0340 | 47.6124 | .0340 |
| 24 | 3 | 1 | 61. | .8026 | .1992 | -4.2716 | .2033 |
| 24 | 4 | 0 | 5. | .0658 | -.0936 | -16.1029 | -.0941 |
| 24 | 5 | 0 | 6. | .0789 | -.3194 | -4.4219 | -.3370 |

TABLE 5. (CONTINUED)

| Item | Choice | Wt | NR | Difficulty | R | X50 | β |
|---|---|---|---|---|---|---|---|
| 25 | 1 | 1 | 27. | .3553 | -.1365 | -2.7191 | -.1378 |
| 25 | 2 | 0 | 1. | .0132 | .1106 | 20.0926 | .1112 |
| 25 | 3 | 0 | 37. | .4868 | .2417 | .1365 | .2491 |
| 25 | 4 | 0 | 1. | .0132 | -.0804 | -27.6273 | -.0807 |
| 25 | 5 | 0 | 10. | .1316 | -.2184 | -5.1244 | -.2238 |
| 26 | 1 | 0 | 2. | .0263 | .1755 | 11.0394 | .1783 |
| 26 | 2 | 1 | 70. | .9211 | .0450 | -31.3498 | .0451 |
| 26 | 3 | 0 | 3. | .0395 | -.1715 | -10.2443 | -.1741 |
| 26 | 4 | 0 | 1. | .0132 | -.0804 | -27.6273 | -.0807 |
| 26 | 5 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 27 | 1 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 27 | 2 | 0 | 2. | .0263 | -.4598 | -4.2151 | -.5177 |
| 27 | 3 | 0 | 5. | .0658 | -.1063 | -14.1906 | -.1069 |
| 27 | 4 | 1 | 67. | .8816 | .2295 | -5.1551 | .2358 |
| 27 | 5 | 0 | 2. | .0263 | -.0627 | -30.9104 | -.0628 |
| 28 | 1 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 28 | 2 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 28 | 3 | 1 | 75. | .9868 | .0327 | -68.0054 | .0327 |
| 28 | 4 | 0 | 1. | .0132 | -.0327 | -68.0054 | -.0327 |
| 28 | 5 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 29 | 1 | 0 | 7. | .0921 | -.1446 | -9.1844 | -.1461 |
| 29 | 2 | 0 | 2. | .0263 | -.0627 | -30.9104 | -.0628 |
| 29 | 3 | 0 | 23. | .3026 | .1909 | 2.7073 | .1945 |
| 29 | 4 | 0 | 22. | .2895 | .1272 | 4.3610 | .1283 |
| 29 | 5 | 1 | 22. | .2895 | -.2411 | -2.3019 | -.2484 |
| 30 | 1 | 1 | 56. | .7368 | .4834 | -1.3109 | .5521 |
| 30 | 2 | 0 | 4. | .0526 | -.1614 | -10.0360 | -.1635 |
| 30 | 3 | 0 | 3. | .0395 | -.4746 | -3.7017 | -.5392 |
| 30 | 4 | 0 | 4. | .0526 | -.2967 | -5.4596 | -.3107 |
| 30 | 5 | 0 | 9. | .1184 | -.3436 | -3.4432 | -.3658 |
| 31 | 1 | 1 | 54. | .7105 | .2694 | -2.0598 | .2797 |
| 31 | 2 | 0 | 21. | .2763 | -.1756 | -3.3814 | -.1784 |
| 31 | 3 | 0 | 1. | .0132 | -.9875 | -2.2496 | -6.2752 |
| 31 | 4 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 31 | 5 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 32 | 1 | 0 | 7. | .0921 | -.2130 | -6.2339 | -.2180 |
| 32 | 2 | 1 | 66. | .8684 | .4152 | -2.6950 | .4564 |
| 32 | 3 | 0 | 2. | .0263 | -.6451 | -3.0043 | -.8442 |
| 32 | 4 | 0 | 1. | .0132 | -.4146 | -5.3580 | -.4556 |
| 32 | 5 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |

TABLE 5. (CONTINUED)

| Item | Choice | Wt | NR | Difficulty | R | X50 | β |
|---|---|---|---|---|---|---|---|
| 33 | 1 | 0 | 11. | .1447 | -.4081 | -2.5955 | -.4470 |
| 33 | 2 | 0 | 5. | .0658 | -.3460 | -4.3580 | -.3688 |
| 33 | 3 | 0 | 1. | .0132 | -.4624 | -4.8047 | -.5214 |
| 33 | 4 | 1 | 59. | .7763 | .5113 | -1.4861 | .5949 |
| 33 | 5 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 34 | 1 | 0 | 2. | .0263 | .1491 | 12.9997 | .1508 |
| 34 | 2 | 0 | 4. | .0526 | -.0562 | -28.8357 | -.0563 |
| 34 | 3 | 1 | 43. | .5658 | .1789 | -.9263 | .1818 |
| 34 | 4 | 0 | 13. | .1711 | .2041 | 4.6549 | .2085 |
| 34 | 5 | 0 | 14. | .1842 | -.4706 | -1.9112 | -.5334 |
| 35 | 1 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 35 | 2 | 0 | 2. | .0263 | -.2745 | -7.0608 | -.2854 |
| 35 | 3 | 1 | 61. | .8026 | .0946 | -8.9994 | .0950 |
| 35 | 4 | 0 | 11. | .1447 | -.0179 | -59.1027 | -.0179 |
| 35 | 5 | 0 | 2. | .0263 | -.0892 | -21.7339 | -.0895 |
| 36 | 1 | 1 | 72. | .9474 | .7627 | -2.1238 | 1.1793 |
| 36 | 2 | 0 | 2. | .0263 | -.7774 | -2.4928 | -1.2360 |
| 36 | 3 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 36 | 4 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 36 | 5 | 0 | 2. | .0263 | -.5656 | -3.4260 | -.6859 |
| 37 | 1 | 0 | 7. | .0921 | -.1153 | -11.5215 | -.1160 |
| 37 | 2 | 0 | 2. | .0263 | .0432 | 44.8699 | .0432 |
| 37 | 3 | 1 | 33. | .4342 | .3793 | .4368 | .4099 |
| 37 | 4 | 0 | 28. | .3684 | -.1934 | -1.7373 | -.1971 |
| 37 | 5 | 0 | 6. | .0789 | -.4071 | -3.4685 | -.4458 |
| 38 | 1 | 0 | 2. | .0263 | -.4068 | -4.7636 | -.4453 |
| 38 | 2 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 38 | 3 | 0 | 13. | .1711 | .0325 | 29.2732 | .0325 |
| 38 | 4 | 0 | 2. | .0263 | -.1156 | -16.7587 | -.1164 |
| 38 | 5 | 1 | 59. | .7763 | .0791 | -9.6115 | .0793 |
| 39 | 1 | 1 | 50. | .6579 | .2629 | -1.5470 | .2725 |
| 39 | 2 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 39 | 3 | 0 | 2. | .0263 | -.3804 | -5.0951 | -.4113 |
| 39 | 4 | 0 | 22. | .2895 | -.1136 | -4.8859 | -.1143 |
| 39 | 5 | 0 | 2. | .0263 | -.5656 | -3.4260 | -.6859 |
| 40 | 1 | 0 | 2. | .0263 | -.0892 | -21.7339 | -.0895 |
| 40 | 2 | 1 | 34. | .4474 | .4114 | .3216 | .4513 |
| 40 | 3 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 40 | 4 | 0 | 38. | .5000 | -.3522 | -.0000 | -.3763 |
| 40 | 5 | 0 | 2. | .0263 | -.2745 | -7.0608 | -.2854 |

TABLE 5. (CONTINUED)

| Item | Choice | Wt | NR | Difficulty | R | X50 | β |
|---|---|---|---|---|---|---|---|
| 41 | 1 | 1 | 67. | .8816 | .4821 | -2.4537 | .5503 |
| 41 | 2 | 0 | 7. | .0921 | -.4183 | -3.1744 | -.4605 |
| 41 | 3 | 0 | 1. | .0132 | -.4624 | -4.8047 | -.5214 |
| 41 | 4 | 0 | 1. | .0132 | -.3191 | -6.9612 | -.3367 |
| 41 | 5 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 42 | 1 | 0 | 19. | .2500 | -.0356 | -18.9596 | -.0356 |
| 42 | 2 | 0 | 13. | .1711 | -.1646 | -5.7713 | -.1669 |
| 42 | 3 | 0 | 2. | .0263 | -.3804 | -5.0951 | -.4113 |
| 42 | 4 | 1 | 41. | .5395 | .1829 | -.5420 | .1860 |
| 42 | 5 | 0 | 1. | .0132 | .1106 | 20.0926 | .1112 |
| 43 | 1 | 0 | 6. | .0789 | -.0450 | -31.3501 | -.0451 |
| 43 | 2 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 43 | 3 | 1 | 61. | .8026 | .1236 | -6.8832 | .1246 |
| 43 | 4 | 0 | 1. | .0132 | -.1759 | -12.6296 | -.1787 |
| 43 | 5 | 0 | 8. | .1053 | -.1195 | -10.4822 | -.1203 |
| 44 | 1 | 0 | 5. | .0658 | -.1189 | -12.6844 | -.1197 |
| 44 | 2 | 0 | 2. | .0263 | -.1951 | -9.9355 | -.1989 |
| 44 | 3 | 0 | 1. | .0132 | -.2236 | -9.9334 | -.2295 |
| 44 | 4 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 44 | 5 | 1 | 68. | .8947 | .1904 | -6.5771 | .1939 |
| 45 | 1 | 0 | 1. | .0132 | -.0327 | -68.0057 | -.0327 |
| 45 | 2 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 45 | 3 | 0 | 2. | .0263 | -.3009 | -6.4397 | -.3156 |
| 45 | 4 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 45 | 5 | 1 | 73. | .9605 | .2283 | -7.6944 | .2345 |
| 46 | 1 | 0 | 2. | .0263 | -.7774 | -2.4928 | -1.2360 |
| 46 | 2 | 0 | 14. | .1842 | .0632 | 14.2275 | .0633 |
| 46 | 3 | 0 | 2. | .0263 | .1755 | 11.0394 | .1783 |
| 46 | 4 | 1 | 56. | .7368 | .1568 | -4.0416 | .1587 |
| 46 | 5 | 0 | 2. | .0263 | -.5127 | -3.7798 | -.5972 |
| 47 | 1 | 0 | 21. | .2763 | -.3205 | -1.8529 | -.3383 |
| 47 | 2 | 1 | 48. | .6316 | .3305 | -1.0168 | .3502 |
| 47 | 3 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 47 | 4 | 0 | 5. | .0658 | -.1315 | -11.4672 | -.1326 |
| 47 | 5 | 0 | 2. | .0263 | -.0098 | -198.7105 | -.0098 |
| 48 | 1 | 0 | 16. | .2105 | -.0277 | -29.0648 | -.0277 |
| 48 | 2 | 0 | 12. | .1579 | .0923 | 10.8652 | .0927 |
| 48 | 3 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 48 | 4 | 1 | 45. | .5921 | .1964 | -1.1863 | .2003 |
| 48 | 5 | 0 | 3. | .0395 | -1.0619 | .0000 | .0000 |

TABLE 5. (CONTINUED)

| Item | Choice | Wt | NR | Difficulty | R | X50 | β |
|---|---|---|---|---|---|---|---|
| 49 | 1 | 0 | 6. | .0789 | -.1657 | -8.5202 | -.1681 |
| 49 | 2 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 49 | 3 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 49 | 4 | 0 | 4. | .0526 | -.2215 | -7.3119 | -.2272 |
| 49 | 5 | 1 | 66. | .8684 | .2259 | -4.9527 | .2319 |
| 50 | 1 | 0 | 9. | .1184 | -.6043 | -1.9574 | -.7585 |
| 50 | 2 | 0 | 2. | .0263 | -.5656 | -3.4260 | -.6859 |
| 50 | 3 | 1 | 57. | .7500 | .7572 | -.8907 | 1.1594 |
| 50 | 4 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 50 | 5 | 0 | 8. | .1053 | -.4741 | -2.6412 | -.5384 |
| 51 | 1 | 0 | 7. | .0921 | .3735 | 3.5548 | .4027 |
| 51 | 2 | 0 | 4. | .0526 | -.2366 | -6.8473 | -.2435 |
| 51 | 3 | 0 | 2. | .0263 | .1226 | 15.8065 | .1235 |
| 51 | 4 | 0 | 11. | .1447 | -.3797 | -2.7895 | -.4105 |
| 51 | 5 | 1 | 52. | .6842 | .1200 | -3.9963 | .1209 |
| 52 | 1 | 1 | 76. | 1.0000 | .0000 | .0000 | .0000 |
| 52 | 2 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 52 | 3 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 52 | 4 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 52 | 5 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 53 | 1 | 0 | 1. | .0132 | -.2236 | -9.9334 | -.2295 |
| 53 | 2 | 0 | 13. | .1711 | -.5269 | -1.8029 | -.6200 |
| 53 | 3 | 0 | 2. | .0263 | -.6186 | -3.1328 | -.7873 |
| 53 | 4 | 0 | 11. | .1447 | .0743 | 14.2559 | .0745 |
| 53 | 5 | 1 | 49. | .6447 | .4357 | -.8518 | .4841 |
| 54 | 1 | 0 | 5. | .0658 | -.4091 | -3.6859 | -.4483 |
| 54 | 2 | 0 | 9. | .1184 | -.3761 | -3.1448 | -.4060 |
| 54 | 3 | 1 | 47. | .6184 | .4992 | -.6036 | .5761 |
| 54 | 4 | 0 | 2. | .0263 | -.8304 | -2.3338 | -1.4902 |
| 54 | 5 | 0 | 13. | .1711 | -.0502 | -18.9300 | -.0502 |
| 55 | 1 | 0 | 5. | .0658 | -.0558 | -27.0298 | -.0559 |
| 55 | 2 | 1 | 67. | .8816 | .2865 | -4.1287 | .2990 |
| 55 | 3 | 0 | 1. | .0132 | .0151 | 147.3452 | .0151 |
| 55 | 4 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 55 | 5 | 0 | 3. | .0395 | -.5883 | -2.9865 | -.7274 |
| 56 | 1 | 0 | 7. | .0921 | -.1153 | -11.5215 | -.1160 |
| 56 | 2 | 0 | 6. | .0789 | -.1109 | -12.7360 | -.1116 |
| 56 | 3 | 1 | 55. | .7237 | .4460 | -1.3314 | .4983 |
| 56 | 4 | 0 | 3. | .0395 | -.7588 | -2.3154 | -1.1649 |
| 56 | 5 | 0 | 5. | .0658 | -.3839 | -3.9282 | -.4157 |

TABLE 5. (CONTINUED)

| Item | Choice | Wt | NR | Difficulty | R | X50 | β |
|---|---|---|---|---|---|---|---|
| 57 | 1 | 0 | 17. | .2237 | -.2195 | -3.4611 | -.2250 |
| 57 | 2 | 0 | 9. | .1184 | -.2947 | -4.0146 | -.3083 |
| 57 | 3 | 0 | 11. | .1447 | .2091 | 5.0659 | .2138 |
| 57 | 4 | 1 | 39. | .5132 | .1916 | -.1721 | .1953 |
| 57 | 5 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 58 | 1 | 0 | 1. | .0132 | -.4624 | -4.8047 | -.5214 |
| 58 | 2 | 0 | 3. | .0395 | .1506 | 11.6690 | .1523 |
| 58 | 3 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 58 | 4 | 1 | 70. | .9211 | .2755 | -5.1264 | .2866 |
| 58 | 5 | 0 | 2. | .0263 | -.6186 | -3.1328 | -.7873 |
| 59 | 1 | 0 | 1. | .0132 | -.9398 | -2.3638 | -2.7501 |
| 59 | 2 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 59 | 3 | 0 | 10. | .1316 | .0618 | 18.1172 | .0619 |
| 59 | 4 | 1 | 48. | .6316 | .4804 | -.6995 | .5478 |
| 59 | 5 | 0 | 17. | .2237 | -.5437 | -1.3975 | -.6478 |
| 60 | 1 | 1 | 68. | .8947 | -.1554 | 8.0584 | -.1573 |
| 60 | 2 | 0 | 5. | .0658 | -.0558 | -27.0298 | -.0559 |
| 60 | 3 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 60 | 4 | 0 | 3. | .0395 | .4158 | 4.2255 | .4572 |
| 60 | 5 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 61 | 1 | 0 | 10. | .1316 | -.4152 | -2.6950 | -.4564 |
| 61 | 2 | 0 | 6. | .0789 | -.5278 | -2.6754 | -.6215 |
| 61 | 3 | 0 | 1. | .0132 | .3493 | 6.3602 | .3728 |
| 61 | 4 | 1 | 59. | .7763 | .5167 | -1.4706 | .6035 |
| 61 | 5 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 62 | 1 | 1 | 55. | .7237 | .0742 | -8.0019 | .0744 |
| 62 | 2 | 0 | 5. | .0658 | -.5605 | -2.6902 | -.6768 |
| 62 | 3 | 0 | 14. | .1842 | .1663 | 5.4070 | .1687 |
| 62 | 4 | 0 | 2. | .0263 | .0432 | 44.8699 | .0432 |
| 62 | 5 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 63 | 1 | 0 | 14. | .1842 | .6153 | 1.4619 | .7805 |
| 63 | 2 | 1 | 8. | .1053 | -.0840 | -14.9081 | -.0843 |
| 63 | 3 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 63 | 4 | 0 | 10. | .1316 | -.0669 | -16.7153 | -.0671 |
| 63 | 5 | 0 | 44. | .5789 | -.3432 | .5805 | -.3654 |
| 64 | 1 | 0 | 9. | .1184 | -.1154 | -10.2528 | -.1162 |
| 64 | 2 | 1 | 26. | .3421 | -.0958 | -4.2449 | -.0963 |
| 64 | 3 | 0 | 2. | .0263 | -.4068 | -4.7636 | -.4453 |
| 64 | 4 | 0 | 37. | .4868 | .1445 | .2282 | .1461 |
| 64 | 5 | 0 | 2. | .0263 | .4138 | 4.6834 | .4545 |

TABLE 5. (CONTINUED)

| Item | Choice | Wt | NR | Difficulty | R | X50 | β |
|---|---|---|---|---|---|---|---|
| 65 | 1 | 0 | 2. | .0263 | -.8039 | -2.4107 | -1.3516 |
| 65 | 2 | 1 | 60. | .7895 | .6488 | -1.2402 | .8526 |
| 65 | 3 | 0 | 8. | .1053 | -.3943 | -3.1757 | -.4290 |
| 65 | 4 | 0 | 6. | .0789 | -.4510 | -3.1310 | -.5054 |
| 65 | 5 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 66 | 1 | 0 | 2. | .0263 | -.1951 | -9.9355 | -.1989 |
| 66 | 2 | 0 | 36. | .4737 | -.5624 | -.1174 | -.6802 |
| 66 | 3 | 0 | 4. | .0526 | -.0111 | -146.2387 | -.0111 |
| 66 | 4 | 1 | 33. | .4342 | .6091 | .2720 | .7681 |
| 66 | 5 | 0 | 1. | .0132 | -.0804 | -27.6273 | -.0807 |
| 67 | 1 | 0 | 1. | .0132 | -.0327 | -68.0057 | -.0327 |
| 67 | 2 | 1 | 72. | .9474 | .2817 | -5.7509 | .2936 |
| 67 | 3 | 0 | 3. | .0395 | -.3420 | -5.1371 | -.3639 |
| 67 | 4 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 67 | 5 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 68 | 1 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 68 | 2 | 1 | 70. | .9211 | .6156 | -2.2939 | .7812 |
| 68 | 3 | 0 | 1. | .0132 | -.4624 | -4.8047 | -.5214 |
| 68 | 4 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 68 | 5 | 0 | 5. | .0658 | -.5858 | -2.5743 | -.7227 |
| 69 | 1 | 0 | 7. | .0921 | -.3499 | -3.7953 | -.3735 |
| 69 | 2 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 69 | 3 | 0 | 3. | .0395 | -.3041 | -5.7771 | -.3192 |
| 69 | 4 | 1 | 54. | .7105 | .3733 | -1.4866 | .4024 |
| 69 | 5 | 0 | 12. | .1579 | -.1822 | -5.5062 | -.1853 |
| 70 | 1 | 0 | 5. | .0658 | .0325 | 46.3367 | .0326 |
| 70 | 2 | 1 | 37. | .4868 | .0190 | 1.7387 | .0190 |
| 70 | 3 | 0 | 15. | .1974 | .0915 | 9.3004 | .0919 |
| 70 | 4 | 0 | 5. | .0658 | .0956 | 15.7674 | .0961 |
| 70 | 5 | 0 | 14. | .1842 | -.1855 | -4.8486 | -.1888 |
| 71 | 1 | 1 | 57. | .7500 | .6607 | -1.0209 | .8801 |
| 71 | 2 | 0 | 16. | .2105 | -.5369 | -1.4987 | -.6364 |
| 71 | 3 | 0 | 1. | .0132 | -.9398 | -2.3638 | -2.7501 |
| 71 | 4 | 0 | 2. | .0263 | -.3804 | -5.0951 | -.4113 |
| 71 | 5 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 72 | 1 | 1 | 39. | .5132 | .4428 | -.0745 | .4938 |
| 72 | 2 | 0 | 2. | .0263 | -.6980 | -2.7764 | -.9747 |
| 72 | 3 | 0 | 8. | .1053 | -.2968 | -4.2193 | -.3108 |
| 72 | 4 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 72 | 5 | 0 | 27. | .3553 | -.2146 | -1.7298 | -.2197 |

TABLE 5. (CONTINUED)

| Item | Choice | Wt | NR | Difficulty | R | X50 | β |
|---|---|---|---|---|---|---|---|
| 73 | 1 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 73 | 2 | 0 | 1. | .0132 | .1583 | 14.0329 | .1603 |
| 73 | 3 | 1 | 67. | .8816 | .4250 | -2.7830 | .4696 |
| 73 | 4 | 0 | 2. | .0263 | -.8039 | -2.4107 | -1.3516 |
| 73 | 5 | 0 | 6. | .0789 | -.2755 | -5.1264 | -.2866 |
| 74 | 1 | 0 | 1. | .0132 | -.2236 | -9.9334 | -.2295 |
| 74 | 2 | 0 | 1. | .0132 | -.4624 | -4.8047 | -.5214 |
| 74 | 3 | 0 | 6. | .0789 | .0537 | 26.2936 | .0538 |
| 74 | 4 | 0 | 13. | .1711 | -.4825 | -1.9691 | -.5508 |
| 74 | 5 | 1 | 55. | .7237 | .4122 | -1.4405 | .4525 |
| 75 | 1 | 0 | 10. | .1316 | .1678 | 6.6702 | .1702 |
| 75 | 2 | 0 | 12. | .1579 | .0388 | 25.8790 | .0388 |
| 75 | 3 | 1 | 44. | .5789 | .2886 | -.6902 | .3014 |
| 75 | 4 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 75 | 5 | 0 | 10. | .1316 | -.7407 | -1.5106 | -1.1027 |
| 76 | 1 | 1 | 68. | .8947 | .3234 | -3.8722 | .3417 |
| 76 | 2 | 0 | 1. | .0132 | -.0327 | -68.0057 | -.0327 |
| 76 | 3 | 0 | 4. | .0526 | -.1313 | -12.3333 | -.1325 |
| 76 | 4 | 0 | 1. | .0132 | -.1282 | -17.3348 | -.1292 |
| 76 | 5 | 0 | 1. | .0132 | -.2236 | -9.9334 | -.2295 |
| 77 | 1 | 0 | 3. | .0395 | -.9861 | -1.7816 | -5.9323 |
| 77 | 2 | 1 | 68. | .8947 | .9528 | -1.3141 | 3.1388 |
| 77 | 3 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 77 | 4 | 0 | 5. | .0658 | -.6993 | -2.1562 | -.9784 |
| 77 | 5 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 78 | 1 | 1 | 48. | .6316 | .1763 | -1.9061 | .1791 |
| 78 | 2 | 0 | 3. | .0395 | -.4935 | -3.5596 | -.5675 |
| 78 | 3 | 0 | 1. | .0132 | -.9875 | -2.2496 | -6.2752 |
| 78 | 4 | 0 | 18. | .2368 | .1553 | 4.6127 | .1572 |
| 78 | 5 | 0 | 6. | .0789 | -.2645 | -5.3391 | -.2743 |
| 79 | 1 | 0 | 25. | .3289 | -.2193 | -2.0196 | -.2247 |
| 79 | 2 | 1 | 41. | .5395 | .3374 | -.2937 | .3585 |
| 79 | 3 | 0 | 3. | .0395 | -.1715 | -10.2443 | -.1741 |
| 79 | 4 | 0 | 7. | .0921 | -.2423 | -5.4794 | -.2498 |
| 79 | 5 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 80 | 1 | 0 | 1. | .0132 | -.9398 | -2.3638 | -2.7501 |
| 80 | 2 | 0 | 2. | .0263 | -.1421 | -13.6369 | -.1436 |
| 80 | 3 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 80 | 4 | 1 | 55. | .7237 | .6730 | -.8824 | .9098 |
| 80 | 5 | 0 | 18. | .2368 | -.5982 | -1.1978 | -.7465 |

TABLE 5. (CONTINUED)

| Item | Choice | Wt | NR | Difficulty | R | X50 | β |
|---|---|---|---|---|---|---|---|
| 81 | 1 | 1 | 56. | .7368 | .3003 | -2.1102 | .3148 |
| 81 | 2 | 0 | 4. | .0526 | -.4170 | -3.8849 | -.4587 |
| 81 | 3 | 0 | 1. | .0132 | -.9875 | -2.2496 | -6.2752 |
| 81 | 4 | 0 | 1. | .0132 | -.4624 | -4.8047 | -.5214 |
| 81 | 5 | 0 | 14. | .1842 | -.0156 | -57.4909 | -.0156 |
| 82 | 1 | 0 | 11. | .1447 | -.1740 | -6.0878 | -.1767 |
| 82 | 2 | 0 | 3. | .0395 | -.1715 | -10.2443 | -.1741 |
| 82 | 3 | 0 | 5. | .0658 | -.4722 | -3.1934 | -.5357 |
| 82 | 4 | 1 | 54. | .7105 | .3875 | -1.4322 | .4203 |
| 82 | 5 | 0 | 3. | .0395 | -.2094 | -8.3905 | -.2141 |
| 83 | 1 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 83 | 2 | 0 | 1. | .0132 | -.0327 | -68.0057 | -.0327 |
| 83 | 3 | 0 | 4. | .0526 | -.4320 | -3.7497 | -.4790 |
| 83 | 4 | 0 | 1. | .0132 | -.4624 | -4.8047 | -.5214 |
| 83 | 5 | 1 | 70. | .9211 | .4291 | -3.2911 | .4750 |
| 84 | 1 | 0 | 3. | .0395 | -.5125 | -3.4280 | -.5968 |
| 84 | 2 | 0 | 2. | .0263 | -.0892 | -21.7339 | -.0895 |
| 84 | 3 | 1 | 66. | .8684 | .3168 | -3.5323 | .3340 |
| 84 | 4 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 84 | 5 | 0 | 5. | .0658 | -.1441 | -10.4631 | -.1456 |
| 85 | 1 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 85 | 2 | 0 | 1. | .0132 | -.4624 | -4.8047 | -.5214 |
| 85 | 3 | 1 | 75. | .9868 | .4624 | -4.8048 | .5214 |
| 85 | 4 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 85 | 5 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 86 | 1 | 0 | 4. | .0526 | -.7778 | -2.0827 | -1.2373 |
| 86 | 2 | 0 | 1. | .0132 | -.0804 | -27.6273 | -.0807 |
| 86 | 3 | 0 | 2. | .0263 | -.0627 | -30.9104 | -.0628 |
| 86 | 4 | 1 | 89. | .9079 | .5454 | -2.4347 | .6507 |
| 86 | 5 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 87 | 1 | 0 | 14. | .1842 | -.0460 | -19.5628 | -.0460 |
| 87 | 2 | 0 | 2. | .0263 | .0961 | 20.1590 | .0966 |
| 87 | 3 | 1 | 48. | .6316 | .4033 | -.8332 | .4407 |
| 87 | 4 | 0 | 8. | .1053 | -.5095 | -2.4574 | -.5922 |
| 87 | 5 | 0 | 4. | .0526 | -.4921 | -3.2915 | -.5653 |
| 88 | 1 | 0 | 0. | .0000 | .0000 | .0000 | .0000 |
| 88 | 2 | 0 | 2. | .0263 | -.4598 | -4.2151 | -.5177 |
| 88 | 3 | 0 | 1. | .0132 | -.3191 | -6.9612 | -.3367 |
| 88 | 4 | 1 | 72. | .9474 | .3117 | -5.1963 | .3281 |
| 88 | 5 | 0 | 1. | .0132 | .1583 | 14.0329 | .1603 |

TABLE 5. (CONTINUED)

| Item | Choice | Wt | NR | Difficulty | R | X50 | β |
|---|---|---|---|---|---|---|---|
| 89 | 1 | 1 | 45. | .5921 | .4418 | -.5273 | .4925 |
| 89 | 2 | 0 | 15. | .1974 | -.4202 | -2.0254 | -.4631 |
| 89 | 3 | 0 | 4. | .0526 | -.0712 | -22.7482 | -.0714 |
| 89 | 4 | 0 | 11. | .1447 | -.0889 | -11.9199 | -.0892 |
| 89 | 5 | 0 | 1. | .0132 | -.7966 | -2.7889 | -1.3176 |
| 90 | 1 | 0 | 12. | .1579 | -.0215 | -46.6671 | -.0215 |
| 90 | 2 | 0 | 4. | .0526 | -.6274 | -2.5818 | -.8058 |
| 90 | 3 | 1 | 24. | .3158 | -.1699 | -2.8216 | -.1725 |
| 90 | 4 | 0 | 22. | .2895 | .5381 | 1.0313 | .6383 |
| 90 | 5 | 0 | 14. | .1842 | -.1916 | -4.6951 | -.1952 |

# APPENDIX C

## EVALUATION INSTRUMENT

## PART I, PART II, AND KEY

PROJECT EVALUATION INSTRUMENT

PART I

Instructions for taking this test:

1. Read the test items carefully and attempt to answer all of them.

2. Choose the best answer for each item and write the letter of your choice in the space provided on your answer sheet.

3. Try to make your choice final so that you don't have to change it. If you do have to change an answer make a heavy X through your previous choice. Questions with more than one answer will be marked wrong.

4. You will have the whole period in which to do this test.

5. DO NOT WRITE IN THIS TEST BOOKLET.

6. ANSWER ALL QUESTIONS.

7. CHOOSE ONLY ONE ANSWER FOR EACH ITEM.

# PROJECT EVALUATION INSTRUMENT

## Part I - Test

1. Galileo, the beneficiary of wealthy patrons, contributed much to science. Which of the following was one of his contributions?

   a. He made a marine chronometer for ships which is used today.
   b. He invented a method for pumping water from coal mines.
   c. He invented a lamp for mines which did not cause coal gas explosions.
   d. He advocated the formation of university research studies.
   e. He presented ideas that cast doubt on Aristotle as the final authority in science.

2. Technological activities resulting in inventions such as the telescope are

   a. not scientific in method or design.
   b. unimportant for science and scientists.
   c. motivated by the desire to produce a specific product.
   d. not practiced by scientists in the United States.
   e. unorganized groping for tools by craftsmen.

3. Until the 17th Century, scientific and social thought was dominated by the ideas of the

   a. Egyptians.
   b. Mesopotamians.
   c. Greeks.
   d. Romans.
   e. Christians.

4. What method would Plato have used to explain phenomena in nature?

   a. Perform a series of laboratory experiments.
   b. Make extensive measurements and calculations.
   c. Read available reports of other scientists.
   d. Sit down and think.
   e. Get the opinion of Aristotle and Archimedes.

5. Which of the following ideas was an important part of the philosophy of Thales?

   a. The universe was a sphere.
   b. A fundamental substance in nature was water.
   c. Natural processes were dependent upon supernatural spirits.
   d. Air was the primary substance in nature.
   e. Only animal matter was capable of life.

6. Aristotle's concept of the nature of matter led

   a. to the discovery of the electron.
   b. alchemists to believe that lead could be changed into gold.
   c. to the adoption of the phlogiston theory.
   d. to the discovery of the proton.
   e. none of the above.

7. The development of the procedures that led to the release of atomic energy is the result of the labors of

   a. the "Fermi Five" scientists.
   b. United States and British scientists.
   c. several refugees from Germany.
   d. United States and German scientists.
   e. scientists from many countries.

8. If science had its historical roots in the technical and spiritual traditions, then science may be best described as

   a. an organized body of knowledge.
   b. an unchanging quest for personal power.
   c. a collection of facts and superstitions.
   d. an organized social activity.
   e. a special activity for a select few.

9. Unexpected but fortunate discoveries often play an important part in scientific investigations. An example of an unexpected discovery is

   a. Roentgen's discovery of the x-ray.
   b. Becquerel's discovery of radioactivity.
   c. the Curies' discovery of radium.
   d. the discovery of nuclear fission.
   e. all of the above.

10. Compared to the early scientist, the scientist of today

    a. is more serious.
    b. has more background knowledge.
    c. is more intelligent.
    d. has more imagination.
    e. is more superstitious.

11. The change in scientific inquiry during the 17th Century could best be described as follows:

    a. Observations were distorted to fit "self-evident truths."
    b. Facts were interpreted according to authority.
    c. Theories were formulated to be consistent with observations.
    d. "Self-evident truths" resulted in accurate observations.
    e. None of the above.

12. During Medieval times Arab scientists such as al-Kindi were patronized by Arab leaders who wanted

    a. the secret of making paper.
    b. to produce brass cannons.
    c. better methods of making glass.
    d. a cure for desert disease.
    e. to gather scientific knowledge.

13. Thales' theory about water being a primordal substance is an example of a(n)

    a. incorrect conclusion based upon direct observations.
    b. early Egyptian scientific thought.
    c. early Roman scientific thought.
    d. correct conclusion based upon indirect observations.
    e. belief about nature based upon superstitions.

14. The results of scientific research

    a. may be kept secret if a scientists desires.
    b. should be kept secret until all consequences are known.
    c. should be made available to other scientists.
    d. rarely need future revision.
    e. should be cleared for publication by governmental agencies.

15. There was very little progress in the development of new ideas of the nature of matter during Medieval times. One explanation is that most Medieval scientists were members of religious orders and

   a. could not read or understand Latin.
   b. were not permitted to study nature.
   c. were concerned with the study of the Islamic religion.
   d. were advocates of Aristotle's ideas.
   e. none of the above.

16. Which of the following countries gave the least support to basic scientific research prior to World War II?

   a. England.
   b. Germany.
   c. Italy.
   d. The Soviet Union.
   e. The United States.

17. Complete the following to best describe the history of the concept of the atom. The atom has been visualized

   a. as a solid sphere.
   b. as a miniature solar system.
   c. as a mathematical model.
   d. differently by different societies.
   e. None of the above is correct.

18. Which of the following best explains why empirical science first flourished in Italy, France, and England?

   a. Empirical science requires financial support.
   b. These countries had a greater number of intelligent people.
   c. Empirical science was more popular in these countries.
   d. These countries had a very strong scientific organization.
   e. Technology was discouraged while empirical science was encouraged.

19. Which of the following encouraged controlled nuclear assistance to developing nations?

   a. Atoms for Peace.
   b. Atomic Energy Act.
   c. Marshall Plan.
   d. Baruch Plan.
   e. Truman Doctrine.

20. Social techniques are needed to insure that

    a. radioactive fallout does not exceed a certain maximum.
    b. decisions made by politicians with the aid of a few scientists will reflect the needs of society.
    c. scientific patents become part of the national scientific society.
    d. the secrets of atomic energy do not become public knowledge.
    e. science and society do not become interrelated.

21. Which of the following represents an example of the interrelationship of scientists and society?

    a. Some scientists had to rely on the patronage of wealthy benefactors.
    b. Some scientists were priestly scribes who helped manage the lives of their people.
    c. Some scientists have been members of university faculties.
    d. Some scientists have been private tutors to students interested in science.
    e. All the choices represent examples of the interrelationship of science and society.

22. One reason why scientists cannot take a "neutral" position toward the results of their work is

    a. they must apply for patents in order to receive credit for their work.
    b. their scientific discoveries could have consequences for society.
    c. scientists are more intelligent than most people.
    d. society wants scientists to become political leaders.
    e. not related to any of the above choices.

23. Which country could benefit from a well-established scientific community?

    a. The Soviet Union.
    b. England.
    c. Brazil.
    d. Norway.
    e. Canada.

24. Active participation of scientists in United States politics is

    a. a myth encouraged by scientists.
    b. the result of the drafting of scientists during World War II.
    c. primarily due to the development of atomic energy.
    d. based on the need for intelligent advisors.
    e. encouraged by the military who desire the advice of scientists.

25. Which of the following is the predictive science practiced by Mesopotamian scribes?

a. Calendar development.
b. Surgical medicine.
c. Astrological forecasting.
d. Development of geometry.
e. Magical horoscopes.

26. Which of the following best describes the relationship between theoretical science and the U.S. government before 1939?

a. The U.S. government provided large sums of money for university science research.
b. The U.S. government did not have a regular program for supporting university science.
c. U.S. scientists were represented by a special advisor to the President.
d. U.S. scientists were represented in the U.S. Congress by a special delegation.
e. The U.S. government promoted research by awarding contracts to deserving scientists.

27. Prior to World War II, Central Europe witnessed a period of political instability and intolernace which resulted in

a. the development of strong scientific societies.
b. the encouragement of theoretical science.
c. the decline of technology.
d. the migration of scientists to other countries.
e. no noticeable change in European science.

28. One of the largest integrated science and technological endeavors directed by the U.S. Army Engineers was known as the

a. St. Lawrence Seaway Project.
b. Project Mohole.
c. Manhattan Project.
d. Cape Kennedy Space Program.
e. Lewis and Clark Expedition.

29. During which century did scientific developments begin to have practical and therefore economic consequences for people?

a. 15th.
b. 16th.
c. 17th.
d. 18th.
e. 19th.

30. An example of society's intolerance of science and the scientist was the condemnation of

    a. Galileo for defending the heliocentric concept of the universe.
    b. Dalton for proposing the concept of the atom.
    c. Aristotle for establishing the concept of final cause.
    d. Rutherford for being the first scientist to artificially produce an element.
    e. Society has not been intolerant of science and scientists.

31. The solar system model of the atom--an atom with a positive nucleus surrounded by negatively charged electrons--was formulated by

    a. Ernest Rutherford.
    b. Niels Bohr.
    c. Enrico Fermi.
    d. Galileo Galilei.
    e. Albert Einstein.

32. Uranium-235 and uranium-238 isotopes differ in mass because

    a. U-238 has more protons than U-235.
    b. U-238 has more neutrons than U-235.
    c. U-238 has more electrons than U-235.
    d. All of the above are correct.
    e. None of the above are correct.

33. The explosion of an atom bomb produces energy in the form of

    a. thermal (heat) radiation.
    b. gamma radiation.
    c. rapidly moving fragments.
    d. all of the above.
    e. none of the above.

34. Which of the following describes a difference between nuclear and chemical reactions?

    a. There is no difference between the two.
    b. Chemical reactions result in new atoms but nuclear reactions do not.
    c. Nuclear reactions result in new atoms but chemical reactions do not.
    d. Chemical reactions involve electrons but nuclear reactions do not.
    e. None of the above are correct.

35. Atomic energy, one of the biggest scientific, technological, and business enterprises of the United States,

a. is of little value to society.
b. has had little influence on industry.
c. developed from discoveries in basic research.
d. is mainly an instrument of the military.
e. all of the above are correct.

36. Nuclear changes may be brought about by

a. penetrating the atomic nucleus with particles.
b. subjecting the atomic nucleus to extremely high pressure.
c. placing the atomic nucleus in highly concentrated acid.
d. subjecting the atomic nucleus to extremely low temperature.
e. all of the above.

37. A nuclear fission reaction could be represented by the following:

$${}^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{131}_{50}Sn + {}^{103}_{42}Mo + 2\,{}^{1}_{0}n$$

Which of the following is a nuclear fusion reaction?

a. ${}^{4}_{2}He + {}^{14}_{7}N \longrightarrow {}^{17}_{8}O + {}^{1}_{1}H$

b. ${}^{30}_{15}P \longrightarrow {}^{30}_{14}Si + {}^{0}_{1}e$

c. ${}^{1}_{1}H + {}^{2}_{1}H \longrightarrow {}^{3}_{2}He$

d. ${}^{238}_{92}U + {}^{2}_{1}H \longrightarrow {}^{238}_{93}Np + 2\,{}^{1}_{0}n$

e. ${}^{239}_{93}Np \longrightarrow {}^{239}_{94}Pu + {}^{0}_{-1}e$

38. The use of the neutron to bombard the nucleus ultimately led to the discovery of

    a. x-rays.
    b. radium.
    c. artificial radioactivity.
    d. the nucleus.
    e. nuclear fission.

39. Radioisotopes are used in medicine and industry as

    a. tracers.
    b. sources of electricity.
    c. sources of light.
    d. all of the above.
    e. none of the above.

40. The world is faced with a problem of the safe disposal of radioactive waste materials because

    a. radioactive fallout cannot be removed from the atmosphere.
    b. radioactive materials cannot be neutralized by any known process.
    c. the wastes are at a dangerous limit.
    d. all of the above.
    e. none of the above.

41. If radioactive substance "A" has a half-life of 10 years, how much of a 1 gram sample of "A" will remain after 20 years?

    a. .25 grams.
    b. .5 grams.
    c. 1 gram.
    d. 2 grams.
    e. 4 grams.

42. The mass that is apparently lost when a nucleus splits appears as

    a. neutrons.
    b. radioactive particles.
    c. electrons.
    d. energy.
    e. none of the above.

43. The necessity for control of all aspects of atomic energy is based upon the fact that

  a. fissionable materials can explode during production.
  b. technology tor producing fissionable material is a military secret.
  c. fissionable material for peaceful and military purposes have the same source.
  d. scientists cannot be trusted with this knowledge.
  e. none of the above.

44. A nuclear power reactor would be useful in which of the following countries?

  a. India.
  b. Brazil.
  c. Egypt.
  d. Italy.
  e. All of the above.

45. The greatest problem in the utilization of radioactive materials is the

  a. danger of an explosion of U-235.
  b. mining of pitchblende.
  c. separation of U-235 from graphite.
  d. packaging of reactor fuel.
  e. radiation hazard to people.

# PROJECT EVALUATION INSTRUMENT

## Part I - Answer Sheet

Fill in these blanks first:

Name ______KEY______

Grade ____________ Age ____________

Class Period ____________

Male ____________ Female ____________

| | | | | | |
|---|---|---|---|---|---|
| 1 | e | 16 | e | 31 | a |
| 2 | c | 17 | d | 32 | b |
| 3 | c | 18 | a | 33 | d |
| 4 | d | 19 | a | 34 | c |
| 5 | b | 20 | b | 35 | c |
| 6 | b | 21 | e | 36 | a |
| 7 | e | 22 | b | 37 | c |
| 8 | d | 23 | c | 38 | e |
| 9 | e | 24 | c | 39 | a |
| 10 | b | 25 | a | 40 | b |
| 11 | c | 26 | b | 41 | a |
| 12 | e | 27 | d | 42 | d |
| 13 | a | 28 | c | 43 | c |
| 14 | c | 29 | e | 44 | e |
| 15 | d | 30 | a | 45 | e |

# PROJECT EVALUATION INSTRUMENT

## Part I - Answer Sheet

Fill in these blanks first:

Name ____________________

Grade __________ Age __________

Class Period ____________________

Male __________ Female __________

| | | |
|---|---|---|
| 1 ____ | 16 ____ | 31 ____ |
| 2 ____ | 17 ____ | 32 ____ |
| 3 ____ | 18 ____ | 33 ____ |
| 4 ____ | 19 ____ | 34 ____ |
| 5 ____ | 20 ____ | 35 ____ |
| 6 ____ | 21 ____ | 36 ____ |
| 7 ____ | 22 ____ | 37 ____ |
| 8 ____ | 23 ____ | 38 ____ |
| 9 ____ | 24 ____ | 39 ____ |
| 10 ____ | 25 ____ | 40 ____ |
| 11 ____ | 26 ____ | 41 ____ |
| 12 ____ | 27 ____ | 42 ____ |
| 13 ____ | 28 ____ | 43 ____ |
| 14 ____ | 29 ____ | 44 ____ |
| 15 ____ | 30 ____ | 45 ____ |

# PROJECT EVALUATION INSTRUMENT

## PART II

Instructions for taking this test:

1. Read the test items carefully and attempt to answer all of them.
2. Choose the best answer for each item and write the letter of your choice in the space provided on your answer sheet.
3. Try to make your choice final so that you don't have to change it. If you do have to change an answer make a heavy X through your previous choice. Questions with more than one answer will be marked wrong.
4. You will have the whole period in which to do this test.
5. DO NOT WRITE IN THIS TEST BOOKLET.
6. ANSWER ALL QUESTIONS.
7. CHOOSE ONLY ONE ANSWER FOR EACH ITEM.

# PROJECT EVALUATION INSTRUMENT

## Part II - Test

46. Early scientists relied on magic as well as science. Which of the following best describes the characteristics of science?

    a. It deals with the control of the supernatural.
    b. It is an attempt to control natural phenomenon which man cannot control.
    c. It is taught through mysterious initiations and myths.
    d. It is a form of activity guided by reason and corrected by observation.
    e. It is handed on from father to son or other similar relationships.

47. Science based upon direct or indirect observation is called

    a. theoretical science.
    b. empirical science.
    c. technological science.
    d. research science.
    e. applied science.

48. The modern atomic theory used to explain certain regularities that existed in the interactions of matter was suggested by

    a. Niels Bohr.
    b. Ernest Rutherford.
    c. Albert Einstein.
    d. John Dalton.
    e. Enrico Fermi.

49. Which of the following statements concerning <u>scientific method</u> is the <u>most</u> accurate?

    a. The scientific method consists of seven steps that are followed by scientists.
    b. Modern scientific method is more observational than experimental.
    c. Use of the scientific method guarantees success in those instances where it is used.
    d. Most research scientists do not follow any sort of scientific method.
    e. There are many different scientific methods used by scientists.

50. Who were responsible for the primary discoveries that led to the harnessing of atomic energy?

    a. The Atomic Energy Commission.
    b. A team of Norwegian scientists with the aid of British scientists.
    c. A few scientists, refugees of Italy and Germany.
    d. A team of British-trained Canadian scientists.
    e. Albert Einstein, Thomas Graham, and John Dalton.

51. Which of the following best describes how Francis Bacon would have studied nature?

    a. Make extensive measurements and calculations.
    b. Read available reports of other scientists.
    c. Get the opinion of mathematicians.
    d. Sit, think, and draw diagrams.
    e. Make observations and recordings of factual evidence.

52. Empedocles proposed the idea that all matter was produced by the union of four elements which were

    a. water, air, earth, and fire.
    b. bile, blood, ether, and form.
    c. quicksilver, sulfur, salt, and gases.
    d. gold, silver, copper, and bronze.
    e. none of the above.

53. Aristotle believed that matter was

    a. composed of special spirits.
    b. composed of water.
    c. unreal and invisible.
    d. discontinuous and made of atoms.
    e. continuous and infinitely divisible.

54. Plato and Aristotle abandoned the effort to use physical forces to explain physical phenomena. What effect did this have on the advance of physical science?

   a. They stimulated the advance of physical science.
   b. They transformed physical science into alchemy.
   c. They delayed the advance of physical science.
   d. They had no effect on the advance of physical science.
   e. They made physical science more empirical.

55. Which of the following is the best description of scientists?

   a. It is easy to divide scientists into separate categories.
   b. It is difficult to divide scientists into separate categories.
   c. Scientists are anti-social.
   d. Scientists usually keep the results of their work secret.
   e. Scientists believe that certain natural phenomena will never be understood.

56. Alchemy was

   a. developed by the early Christians.
   b. promoted by 3rd Century (A.D.) universities.
   c. derived from Greek Alexandrian science.
   d. prohibited by the Pharoahs of Egypt.
   e. not part of the advance of science.

57. One of the first atomic theories suggested that matter was composed of eternally moving indestructible atoms. It was proposed by

   a. Dalton and Thomson.
   b. Rutherford and Bohr.
   c. Aristotle and Plato.
   d. Leucippus and Democritus.
   e. Cicero and Galen.

58. Which of the following is the most crucial test of the validity of a scientists' experimental findings?

   a. It is in agreement with the ideas of Plato.
   b. It can be analyzed mathematically.
   c. It can be published in a scientific journal.
   d. It can be repeated by other scientists.
   e. It produces some useful product.

59. Before the 17th Century most scientists developed generalizations about nature

a. from experiments and calculations.
b. by using the scientific method.
c. by using the methods of Socrates.
d. by developing mental images for deductive reasoning.
e. by inductive reasoning and experimentation.

60. The Arabs made their greatest contribution to science during the Middle Ages by

a. translating and preserving the works of Greek scientists.
b. developing the science of mechanics.
c. formulating the modern atomic theory.
d. founding the first universities.
e. developing a secret method for making gold.

61. Early Egyptian scientists (about 2500 B.C.) practiced the following applied science or technology.

a. Liver divining and horoscoping.
b. Experimentation and astrology.
c. Domestication and harispucy.
d. Medicine and surveying.
e. Antisepsis and biogenesis.

62. What is the significance of December 6, 1941?

a. It marked a change in attitude among U.S. scientists and politicians about national support of research science.
b. It was the day Japan attacked Pearl Harbor and the U.S. government drafted all university scientists.
c. It was the day that the first nuclear reactor went critical at the University of Chicago.
d. It was the day that the construction of Oak Ridge was begun.
e. The events of this day are still top secret so most U.S. citizens do not know the significance of this day.

63. Science is important in

a. giving a complete picture of the universe.
b. establishing the international political position of a country.
c. improving the political position of scientists.
d. increasing the intelligence of people.
e. all of the above.

64. Scientists during the Middle Ages were inspired to use scientific inquiry for

    a. personal financial purposes.
    b. religious and economic purposes.
    c. military and political purposes.
    d. astrological and alchemical purposes.
    e. physical and chemical purposes.

65. Which of the following inventions had a great influence on the advance of science during the late Middle Ages (about A.D. 1500)?

    a. Toricelli's barometer.
    b. Gutenberg's printing press.
    c. Galileo's telescope.
    d. Van Leeuwenhoek's microscope.
    e. Fahrenheit's thermometer.

66. Which of the following may have been factors that contributed to the rise of theoretical science in Ancient Greece (around 600 B.C.)?

    a. The printing press was developed to replace the scribes.
    b. Theoretical science became an activity of craftsmen and priests.
    c. Influence by other foreign countries was prevented by a strong central government.
    d. There was a simple political structure and much commercial travel.
    e. Precise scientific equipment and techniques were developed.

67. Which of the following is an accurate description of the influence of <u>science and technology</u> on society?

    a. <u>Science and technology</u> have not been important in the social development of many countries.
    b. The products of <u>science and technology</u> have been important in the social development of many countries.
    c. Social development does not determine the course of <u>science and technology</u>.
    d. Only <u>technology</u> has an influence on society.
    e. Only <u>science</u> has an influence on society.

68. Science in Ancient Greece (500 B.C.) developed

    a. without regard to the nature of the universe.
    b. as an intellectual activity of the leisure class.
    c. on the basis of induction and experimentation.
    d. for personal and financial gain.
    e. as a practical activity of the craftsmen.

69. The Romans failed to carry on the Greek scientific tradition. One reason for this failure was that the

a. Romans had no need for scientific accomplishments.
b. Romans were not intelligent enough to continue the tradition.
c. Greeks were interested in practical science and the Romans in theoretical science.
d. Romans were interested in applied science rather than pure science.
e. control of the Roman government was more rigid than Greek government.

70. In the late Middle Ages, scientific activity was most closely associated with the

a. academy.
b. university.
c. scientific society.
d. lyceum.
e. craftsman guild.

71. The principal goal of the U.S. for developing nuclear energy during World War II was

a. to deter Hitler from using it as a weapon.
b. to bring the war to an early conclusion.
c. to gain a cheap source of electric power.
d. to advance the frontiers of scientific inquiry.
e. to make scientists part of the war effort.

72. German science began to decline when Hitler gained political control largely because the Nazi's

a. ideals opposed many scientific ideals.
b. jailed most of the leading scientists.
c. prohibited most scientific activities.
d. favored religious groups over scientific groups.
e. removed all Jewish scientists from German universities.

73. Complete the following to best describe the attitude of society toward science in the 20th Century. Society has realized that science is a

a. threat to freedom and has discouraged the pursuit of science.
b. threat to freedom but encourages the pursuit of science anyway.
c. national resource and has promoted its development.
d. All of the above.
e. None of the above.

74. The first U.N. Geneva Conference for the Peaceful Uses of Atomic Energy was a historic event because it was the

a. meeting of diplomats to view a new reactor at Geneva.
b. last time that scientists had any international influence.
c. day that marked a change in diplomatic negotiations.
d. meeting at which science and technology signed a truce.
e. first time diplomats sat together with scientists from various countries.

75. Which country was the first to develop industrial and political strength by nationalizing science?

a. England.
b. France.
c. Germany.
d. The Soviet Union.
e. The United States.

76. Ionizing radiations cause mutations

a. other than those in nature.
b. which are all desirable.
c. which are all undesirable.
d. in plants but not in animals.
e. in animals but not in plants.

77. Which of the following best completes this statement? A nuclear chain reaction

a. can only be very rapid.
b. can be slowed to a controlled rate.
c. cannot be slowed for useful control.
d. can be controlled by adding neutrons.
e. can be controlled by using high temperature reactors.

78. According to Aristotle, water could be changed into

a. air, fire, or earth.
b. iron, gold, or silver.
c. wood, clay, or rock.
d. all of the above.
e. none of the above.

79. Scientists realized that radioactive materials could be a source of electric power because when they decay

a. electrons are released.
b. heat energy is released.
c. light energy is released.
d. binding energy is released.
e. electrons are absorbed.

80. Radioactivity

a. increases with an increase in temperature.
b. increases when the element is in solution.
c. decreases with an increase in pressure.
d. is essentially independent of external influences.
e. is not described by any of the above.

81. Which of the following is a necessary condition for a nuclear chain reaction?

a. Neutrons released must exceed neutrons absorbed.
b. Neutrons released must exceed protons absorbed.
c. Protons released must equal protons absorbed.
d. Electrons must equal neutrons.
e. None of the above are necessary.

82. Which of the following best describes the Atomic Energy Commission?

a. A government agency.
b. A non-military agency.
c. A profit-free agency.
d. All of the above.
e. None of the above.

83. The minimum quantity of uranium-235 necessary to sustain a chain reaction is known as the

a. least square.
b. minimum ratio.
c. k factor.
d. reaction barrier.
e. critical mass.

84. Complete the following to best describe the present status of nuclear power plants. Nuclear power plants are

a. being used more than power plants using fossil fuel.
b. more dependent upon geography than other power plants.
c. more costly to build because they must include many safety devices.
d. the main source of electricity in Europe and the Soviet Union.
e. being built by many countries because these countries are concerned about air pollution.

85. A useful reactor control rod

a. cools the reactor core if the reactor becomes too hot.
b. removes part of the fissionable material when the reactor exceeds a set limit.
c. decreases the rate of nuclear fission by absorbing neutrons.
d. shields workers from excess radiation.
e. decreases the rate of nuclear fission by emitting neutrons.

86. When the nucleus of a uranium-235 atom is penetrated by a neutron, which of the following may occur?

a. The nucleus splits.
b. Neutrons are emitted.
c. Energy is released.
d. All of the above.
e. None of the above.

87. When a charged particle penetrates the nucleus of an atom the result is the formation of a

a. heavier form of the original element.
b. lighter form of the original element.
c. different element.
d. split nucleus.
e. none of the above.

88. An atomic pile can be described as a(n)

a. building where electricity is produced.
b. unexploded atom bomb.
c. place where atomic fuel is stored.
d. assemblage of fissionable material and a moderator.
e. none of the above.

89. Radioisotopes produced during nuclear fission have half-lives that

a. vary over a wide range.
b. are short.
c. are approximately equal.
d. are long.
e. are prolonged by heating.

90. If a quantity of radioactive iodine enters the human body what factors will determine where it will be deposited in the body?

a. The amount of radioactive iodine entering the body.
b. The intensity of radiation of the iodine.
c. The chemical properties of the iodine.
d. The biological properties of the iodine.
e. The nature of the radiation emitted by the iodine.

# PROJECT EVALUATION INSTRUMENT

## Part II - Answer Sheet

Fill in these blanks first:

Name KEY

Grade ______ Age ______

Class Period ______

Male ______ Female ______

| | | | | | |
|---|---|---|---|---|---|
| 46 | d | 61 | d | 76 | a |
| 47 | b | 62 | a | 77 | b |
| 48 | d | 63 | b | 78 | a |
| 49 | e | 64 | b | 79 | b |
| 50 | c | 65 | b | 80 | d |
| 51 | e | 66 | d | 81 | a |
| 52 | a | 67 | b | 82 | d |
| 53 | e | 68 | b | 83 | e |
| 54 | c | 69 | d | 84 | c |
| 55 | b | 70 | b | 85 | c |
| 56 | c | 71 | a | 86 | d |
| 57 | d | 72 | a | 87 | c |
| 58 | d | 73 | c | 88 | d |
| 59 | d | 74 | e | 89 | a |
| 60 | a | 75 | c | 90 | c |

# PROJECT EVALUATION INSTRUMENT

## Part II - Answer Sheet

Fill in these blanks first:

Name ______________________

Grade __________ Age __________

Class Period ______________________

Male __________ Female __________

| | | |
|---|---|---|
| 46 ____ | 61 ____ | 76 ____ |
| 47 ____ | 62 ____ | 77 ____ |
| 48 ____ | 63 ____ | 78 ____ |
| 49 ____ | 64 ____ | 79 ____ |
| 50 ____ | 65 ____ | 80 ____ |
| 51 ____ | 66 ____ | 81 ____ |
| 52 ____ | 67 ____ | 82 ____ |
| 53 ____ | 68 ____ | 83 ____ |
| 54 ____ | 69 ____ | 84 ____ |
| 55 ____ | 70 ____ | 85 ____ |
| 56 ____ | 71 ____ | 86 ____ |
| 57 ____ | 72 ____ | 87 ____ |
| 58 ____ | 73 ____ | 88 ____ |
| 59 ____ | 74 ____ | 89 ____ |
| 60 ____ | 75 ____ | 90 ____ |

APPENDIX D

STUDENT RESPONSE QUESTIONNAIRE

## STUDENT RESPONSE QUESTIONNAIRE

To the student: Now that you are completing a unit utilizing the socio-historical approach you can help to evaluate this unit by responding to the following items. This is not a test but an opportunity to answer some questions about this approach to teaching science and science related materials. CHECK ONE RESPONSE FOR EACH INQUIRY.

### General Questions

Name ______________________ Period ____________

How many years of each of the following have you taken in high school?

a. Science _____ years
b. Social science _____ years

On the average, how much time did you spend reading each chapter?

_____ Less than ½ hour
_____ ½ hour
_____ 1 hour
_____ 1½ hours
_____ 2 or more hours

What was the maximum amount of time you spent reading any one chapter?

_____ Less than ½ hour
_____ ½ hour
_____ 1 hour
_____ 1½ hours
_____ 2 or more hours

To what extent did you read each of the chapters? (Check one for each chapter.)

| Chapter | all | most | some | none |
|---|---|---|---|---|
| 1 | ____ | ____ | ____ | ____ |
| 2 | ____ | ____ | ____ | ____ |
| 3 | ____ | ____ | ____ | ____ |
| 4 | ____ | ____ | ____ | ____ |
| 5 | ____ | ____ | ____ | ____ |
| 6 | ____ | ____ | ____ | ____ |
| 7 | ____ | ____ | ____ | ____ |
| 8 | ____ | ____ | ____ | ____ |
| 9 | ____ | ____ | ____ | ____ |
| 10 | ____ | ____ | ____ | ____ |
| 11 | ____ | ____ | ____ | ____ |
| 12 | ____ | ____ | ____ | ____ |

## Personal Opinions

When compared to most science materials you have read before, the reading material for this unit is:

____ much more difficult
____ somewhat more difficult
____ about the same difficulty
____ somewhat easier
____ much easier

When compared to most social science materials you have read before, this reading material is:

____ much more difficult
____ somewhat more difficult
____ about the same difficulty
____ somewhat easier
____ much easier

When compared to other science materials, this unit is:

____ much less interesting
____ somewhat less interesting
____ about the same
____ somewhat more interesting
____ much more interesting

When compared to other <u>social science</u> materials, this unit is:

_____ much less interesting
_____ somewhat less interesting
_____ about the same
_____ somewhat more interesting
_____ much more interesting

What effect has this unit had on your interest in science?

_____ increased interest greatly
_____ increased interest somewhat
_____ no change
_____ decreased interest somewhat
_____ decreased interest greatly

Which chapter was

a. most interesting to you? _____
b. least interesting to you? _____

List the following items in the order of interest to you. (Use 1 for most interesting and 5 for least interesting.)

_____ scientific explanations
_____ discussion of history
_____ biographies of scientists
_____ quotations of scientists
_____ discussion of social implications

Which of the following do you think would have helped you to better understand the material in this unit?

_____ more class discussion
_____ more lecture-explanation
_____ more slides and movies
_____ more recitation-drill
_____ more reading

Who would benefit from science instruction utilizing this type of approach?

_____ students interested in a career in science
_____ students not interested in a career in science
_____ all students regardless of interest
_____ no high school students

If you had more time would you have read more about science and its relation to society?

_____ yes
_____ no

If a course utilizing the socio-historical approach were offered would you be interested in taking it?

_____ yes
_____ no

What effect has this unit had on your understanding of the interrelationship between science and society?

_____ increased my understanding greatly
_____ increased my understanding a little
_____ it has not improved my understanding
_____ it has confused me

What effect has this unit had on your understanding of science and scientists?

_____ increased my understanding greatly
_____ increased my understanding a little
_____ it has not improved my understanding
_____ it has confused me

What effect has this unit had on your understanding of the atom and atomic energy?

_____ increased my understanding greatly
_____ increased my understanding a little
_____ it has not improved my understanding
_____ it has confused me

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