8-1966

A Comparative Study of Two Programed Instructional Methods and Conventional Instruction In A Unit Of Ninth Grade Physical Science

Ronald James McKee

Recommended Citation

McKee, Ronald James, "A Comparative Study of Two Programed Instructional Methods and Conventional Instruction In A Unit Of Ninth Grade Physical Science" (1966). *Theses and Dissertations*. 2529.
https://commons.und.edu/theses/2529

A COMPARATIVE STUDY OF TWO PROGRAMED INSTRUCTIONAL METHODS AND CONVENTIONAL INSTRUCTION IN A UNIT OF NINTH GRADE PHYSICAL SCIENCE

by

Ronald J. ames McKee

B.S. in Biology and Physical Science, Valley City State College, 1951
M.E. in Educational Administration, University of North Dakota, 1958
M.A. in Education (Science), State College of Iowa, 1959

A Dissertation

Submitted to the Faculty

of the

University of North Dakota

in partial fulfillment of the requirements

for the Degree of

Doctor of Education

Grand Forks, North Dakota

August
1966

This dissertation submitted by Ronald J. McKee in partial fulfillment of the requirements for the Degree of Doctor of Education in the University of North Dakota is hereby approved by the Committee under whom the work has been done.

Chairman

A L Gray

Virgil I Stenberg

Christopher J. Hamre
Dean of the Graduate School

ACKNOWLEDGMENTS

The writer wishes to express his sincere appreciation to his major advisor, Dr. A. W. Sturges, to Dr. C. A. Hausken, and to Dr. E. H. Nagel for their counsel and aid in this study.

The writer also acknowledges the aid and suggestions of his committee, Dr. A. J. Bjork, Dr. A. L. Gray, Dr. V. I. Stenberg, and Dr. R. A. Peterson.

The writer extends a special note of appreciation to Dr. Ed Krahmer for his aid in programming and data processing and to Arthur Malo, William O'Toole, Henry Koehnlein, Walter Will, and Carol Unkenholz for participating in the study.

TABLE OF CONTENTS

LIST OF TABLES

ABSTRACT

Statement of the Problem

The problem was to determine whether a combination of conventional and programed instruction was more effective than conventional instruction alone in the teaching of a ninth-grade Physical Science unit, "Matter, Atoms, and Molecules." The three treatment groups compared were (1) the Conventional Group, (2) the Introductory Group, in which the programed material was used as initiatory assignments, and (3) the Review Group, in which the programed material was used as review assignments. Student achievement was measured by means of the Adjusted Recall Gain Score, the Adjusted Application Gain Score, and the Adjusted Total Gain Score.

In addition, the problem was to compare the effectiveness of the five Physical Science instructors taking part in the study and to determine if there was a significant correlation between the gain scores and (1) student intelligence, as measured by the CTMM, (2) student ability in mathematics, as measured by the ITED Quantitative Score, (3) student ability in reading material in natural science, as measured by the ITED Science Reading Score, and (4) the student's general achievement level, as measured by the ITED Composite Score.

Methodology

A linear program and a criterion test were prepared by the researcher for the unit, "Matter, Atoms, and Molecules." The program consisted of 619 frames calling for 835 responses. The criterion test was divided into two parts, a Recall Test and an Application Test. Both parts were composed of 30 test items.

Twenty-three intact classroom sections (547 students) were randomly assigned to one of the three treatment groups. The only restriction placed on the assignment of the sections was that each of the five teachers should have at least one section, but no more than two sections, in each of the treatment groups.

The criterion test was administered as the pre-test and as the post-test. The ITED and CTMM tests had been administered to the students prior to the study.

Students using the programed material were asked to complete a short questionnaire designed to determine their reaction to the programed material. The teachers were asked to provide background information relative to their own experience and training.

Results

1. There was no significant difference between the three adjusted gain scores of the three treatment groups, although the Review Group had the highest Adjusted Recall Gain Score and the highest Adjusted Application Gain Score.

2. There was a significant difference between the adjusted gain scores of the five teacher groups.

3. There was a significant correlation between the gain scores (Recall, Application, and Total) and the ITED and CTMM scores. These significant correlations held for each of the treatment groups.

4. The students tended to become tired of the programed material toward the end of the unit. However, the majority felt the material had helped them and they expressed a desire to use programed material again.

5. There was no significant correlation between the adjusted gain scores and teacher experience and training except for that between the

Adjusted Application Gain Score and semester hours of Physics.

6. The best single predictor of student success, as measured by the gain scores, was the ITED Composite Score.

Conclusion

The one major conclusion that can be drawn from this study is that the success of the Grand Forks ninth-graders in the Physical Science unit, "Matter, Atoms, and Molecules," is more dependent upon the teacher than upon the instructional methodology.

CHAPTER I

THE PROBLEM AND ITS BACKGROUND

Statement of the Problem

The study attempted to determine whether programed materials were more effective when used as initiatory assignments to supplement conventional instruction in Physical Science or when used as review assignments to supplement conventional instruction; whether either method of using programed materials was more effective than the use of conventional instruction alone; and whether students exposed to adjunct programed materials demonstrated a greater facility for the recall of factual information and for the application of factual information than did the students exposed only to conventional instruction.

The study also attempted to determine whether the Physical Science teachers of the Grand Forks Public Schools varied significantly in effectiveness in teaching for the recall of factual information and for the application of factual information, regardless of the method of instruction that was used.

The interaction of each instructional method with each teacher was studied to determine whether such interaction was significant.

Finally, the study attempted to determine whether the effectiveness of any of the instructional methods was dependent upon:

1. The student's intelligence, as measured by the California Test of Mental Maturity.

2. The student's ability to read materials in natural science, as measured by the Iowa Test of Educational Development.

3. The student's mathematical ability, as measured by the Iowa Test of Educational Development.

4. The student's general achievement level, as measured by the Iowa Test of Educational Development.

The Purpose of the Study

The study tested the following null hypotheses:

1. There is no significant difference in the effectiveness of the three instructional methods, as measured by a criterion test prepared by the researcher, whether that effectiveness is measured by the Adjusted Recall Gain Score, the Adjusted Application Gain Score, or the Adjusted Total Gain Score.

2. There is no significant difference in the effectiveness of the individual teachers, as measured by the criterion test prepared by the researcher, whether that effectiveness is measured by the Adjusted Recall Gain Score, the Adjusted Application Gain Score, or the Adjusted Total Gain Score.

3. There is no significant interaction of the instructional method with the teacher whether such interaction is measured by the Adjusted Recall Gain Score, the Adjusted Application Gain Score, or the Adjusted Total Gain Score.

4. There is no significant correlation between the students' intelligence, as measured by the California Test of Mental Maturity, and the effectiveness of any of the instructional methods used in the study, as measured by the gain scores on the criterion test.

5. There is no significant correlation between the students' ability to read materials in natural science, as measured by the Iowa Test of Educational Development, and the effectiveness of any of the instructional methods used in the study, as measured by the gain scores on the criterion test.

6. There is no significant correlation between the students' mathematical ability, as measured by the Iowa Test of Educational Development, and the effectiveness of any of the instructional methods used in the study, as measured by the gain scores on the criterion test.

7. There is no significant correlation between the students' general achievement level, as measured by the Iowa Test of Educational Development, and the effectiveness of any of the instructional methods used in the study, as measured by the gain scores on the criterion test.

Background of the Problem

James D. Finn notes that there are presently two trends in instructional technology. The first is a trend toward a mass instructional technology and the second is a growing technology for individual instruction.[1] One of the contributions of the latter technology has been the development of auto-instructional devices. Auto-instructional devices are characterized by the controlled presentation of material, the elicitation of the appropriate response, guidance with respect to the subject matter, and control of the way in which learning proceeds.[2]

---

[1] James D. Finn, "A New Theory for Instructional Technology," Audio Visual Communication Review, 1960, 8, pp. 84-94.

[2] Desmond L. Cook, "Teaching Machine Terms: A Glossary," Audiovisual Instruction, 1961, 6, pp. 152-153.

Auto-instruction or, as it is more commonly called, programed instruction has not produced the revolution in education that its ardent adherents predicted several years ago. Yet, there seems to be no doubt that programed learning represents a promising effort toward finding a solution to the problem of individual differences.[1]

David J. Klaus states,

> With the possible exception of large-scale testing, no one development in the field of psychology seems to have as much potential for the better utilization of human resources as auto-instructional methods. The technique has promise for producing a genuine and large scale improvement in educational practices and, as a consequence, it is expected to have a tremendous impact on the quality of classroom instruction. Because of the novelty of the technique and its potential impact on education, it is not at all surprising that auto-instruction is more frequently talked about then understood, and that more predictions are made as to its potentials than facts are collected as to its capabilities.[2]

Colonel Gabriel D. Ofiesh also feels that the future of auto-instruction is promising.

> Automated instruction with its correlative technology still promises the first true and radical innovation in instruction since the invention of movable type.[3]

Research provides over-whelming evidence that programed instructional materials do teach. What is more important, research also indicates that such materials are as effective as conventional instruction. Harry F. Silberman cites fifteen studies comparing programed instruction to conventional instruction. In nine of the studies, programed instruction was significantly better than conventional instruction as determined

---

[1] James D. Finn, "Teaching Machines: Auto-Instructional Devices for the Teacher," NEA Journal, 49 (November, 1960), pp. 41-44.

[2] David J. Klaus, "The Art of Auto-Instructional Programming," Audio Visual Communication Review, 1961, 9, pp. 130-142.

[3] Colonel Gabriel D. Ofiesh, "Introduction," Trends in Programmed Instruction, ed. Gabriel D. Ofiesh and Wesley C. Meierhenry, (Washington: Department of Audiovisual Instruction, 1964), pp. 1-6.

by scores on a criterion test. There was no significant difference in the scores of the two groups in the other six studies. Timewise, programed instruction took significantly less time than conventional instruction in all of the studies.[1]

Other studies by Colwell[2], Geller[3], McMurray[4], Northcutt[5], Beane[6], Brown[7], Grell[8], and Hough[9] all concluded that programed instructional

---

[1] Harry F. Silberman, "Characteristics of Some Recent Studies of Instructional Methods," Programmed Learning and Computer=Based Instruction, ed. John E. Coulson (New York: John Wiley and Sons, Inc., 1962), pp. 18-19.

[2] Dell M. Colwell, "The Effectiveness of Self-Instructional Techniques in Teaching Selected Phases of an Introductory Course in Audio-Visual Education," Dissertation Abstracts, (Ann Arbor: University Microfilms, Inc., 1964), pp. 4565-4566.

[3] Molly S. Geller, "The Measurement of the Effectiveness of a Teaching Machine Program in an Area of College Chemistry," Dissertation Abstracts, 1963, pp. 512-513.

[4] James G. McMurray, "An Experimental Comparison of Self-Instructional Versus Traditional Methods in Teaching Related Information in the Comprehensive General Shop," Dissertation Abstracts, 1965, p. 5793.

[5] Mary P. Northcutt, "The Comparative Effectiveness of Classroom and Programed Instruction in the Teaching of Decimals to Fifth Grade Students," Dissertation Abstracts, 1964, pp. 5091-5092.

[6] Donald G. Beane, "A Comparison of Linear and Branching Techniques of Programed Instruction in Plane Geometry," 1962, cited by Wilbur Schramm, The Research on Programed Instruction, U.S. Dept. of Health, Education, and Welfare Bulletin No. 35 (Washington: U.S. Government Printing Office, 1964), p. 23.

[7] Robert O. Brown, Jr. "A Comparison of Test Scores of Students Using Programed Instructional Materials With Those of Students Not Using Programed Instructional Materials," 1962, cited by Wilbur Schramm, The Research on Programed Instruction, p. 26.

[8] Lewis A. Grell, "Comparative Effectiveness and Efficiency of the Teaching of Spelling by Use of a Programmed Instruction Method and a Conventional Textbook Method," Dissertation Abstracts, 1964, pp. 5242-5243.

[9] John B. Hough, "An Analysis of the Efficiency and Effectiveness of Selected Aspects of Machine Instruction," Journal of Educational Research, 55 (1962), pp. 467-471.

methods were as effective as conventional methods of instruction. Yet, several writers indicate that the evidence is far from conclusive. As Silberman points out,

> Among the 80 experiments reviewed, it was not uncommon to find very short programs, administered in one or two hours to small samples of highly motivated students who viewed the program as a test, followed immediately by a hastily improvised quiz. Wide individual differences completely mask out treatment effects even when criterion measures are sensitive enough to detect them.[1]

Porter adds that in many studies, little if any effort was made to equate the groups for initial proficiency with respect to the subject matter.[2]

Lawrence M. Stolurow argues that comparative studies are premature. We know too little, he feels, about the complex phenomenon called learning to compare methods of instruction.[3] However, Robert Silverman feels that there is a need for such comparisons,

> ...with the present state of teaching-machine programs in mind, many investigators argue that comparative control-group studies would be premature at present. They insist that meaningful comparison can be made only when good programs and machines are available. This argument has considerable merit, but there is still a place for comparison studies even at this early date. Such comparisons may stimulate improvement in programing and machine design. The performance of a control group (taught by conventional methods) can be used as a standard or base line against which to measure the effects of different programing methods and different types of machine presentation.[4]

---

[1] Silberman, Programmed Learning and Computer=Based Instruction, p. 17.

[2] D. Porter, "A Critical Review of a Portion of the Literature on Teaching Devices," Harvard Educational Review, 1957, 27, pp. 126-147.

[3] Lawrence M. Stolurow, "Implications of Current Research and Future Trends," Journal of Educational Research, 55 (1962), pp. 519-527.

[4] Robert E. Silverman, "Auto-Instructional Devices: Some Theoretical and Practical Considerations," Journal of Higher Education, 31 (1960), pp. 481-486.

Robert Goldbeck and Leslie Briggs agree with Silverman,

> Eventual adoption and use of instructional methods should depend on some such comparison of complete methods.[1]

Assuming that Silverman, Goldbeck, and Briggs are correct in their evaluation of comparative studies, the classroom teacher who is interested in making such a study must make several decisions. The first decision is that of choosing the programed material. Though the number of published programs is increasing each year, the teacher may encounter difficulty finding a program that meets his needs. Perhaps the solution to this problem is that suggested by David J. Klaus,

> Sooner or later, educators and teachers are going to have full responsibility for writing programed materials for classroom use...[2]

A second decision that must be made and made in conjunction with the choice of a program is that of determining the number of class periods to be devoted to the comparative study. Most of the early published programs were designed to be used for one semester or for a full year. As Carlton Downing points out,

> It appears that early producers of programs for use in elementary and secondary schools made a serious error in judgment when they chose to program whole courses rather than units or modules of courses. The decision to teach a semester course with a program implies the acceptance of the concept of each student progressing at his own rate of learning.[3]

---

[1] Robert A. Goldbeck and Leslie J. Briggs, "An Analysis of Response Mode and Feedback Factors in Automated Instruction," Programmed Learning, p. 170

[2] David J. Klaus, "The Art of Auto-Instructional Programming," Audio Visual Communication Review, 1961, 9, pp. 130-142.

[3] Carlton Downing, "Programmed Instruction in Perspective," Trends in Programmed Instruction, pp. 31-32.

One can assume from Downing's statement that the response of teachers to the semester-long or year-long programs was less than enthusiastic. This lack of enthusiasm indicates that teachers were reluctant to pursue a semester-long or year-long study when they were not familiar with a particular instructional technique. Thus, the trend toward the publishing of programed units of instruction is a logical one.

Joe Spagnoli reports that the more successful of his experiences with programed instruction have been those involving a specific topic or unit of instruction whereby the students were taught the material over a limited period of time.[1]

Finally, the teacher must make a decision as to the procedure to be followed in utilizing programed materials. In most of the comparative studies which have been made, one of the methods studied has been that involving the exclusive use of programed material. Though this method may have the advantage of flexibility in that it permits students to complete a unit or a course at his own pace, it also creates a problem for the teacher. What is to be done with the students who are turned out of the program at different times? William A. Deterline feels that programers cannot evade their responsibility for this problem.[2]

---

[1] Joe Spagnoli, "Action Research with Programmed Materials," School Science and Mathematics, 65 (1965), pp. 155-158.

[2] William A. Deterline, "Human Systems and Programed Instruction," Program, Teachers, and Machines, ed. Alfred de Grazia and David A. Sohn, (New York: Bantam Books, 1964), pp. 117-126.

Lassar Gotkin states that it is possible to utilize programed instruction without disrupting existing classroom practices. He suggests that teachers use programed materials as homework assignments.[1] D. J. Kalus and W. A. Deterline, on the other hand, suggest that programed materials can be more effective if used in the classroom under the guidance of the teacher and followed by a discussion.[2] Studies by Fishell[3], Goldbeck and others[4], Hatch and Flint[5], and Sargent[6] found that a combination of programed instruction and conventional instruction was significantly better than either programed instruction or conventional instruction alone. The problem is, how should the two forms of instruction be combined? As Silberman says,

---

[1] Lassar G. Gotkin, "Programed Instruction in the Schools: Individual Differences, the Teacher, and Programing Styles," Programs, Teachers, and Machines, pp. 159-171.

[2] D.J. Klaus and W.A. Deterline, "Student Reactions to Auto-Instruction," (Pittsburgh: American Institute for Research, 1961) as cited by William Deterline, Programs, Teachers, and Machines, p. 123.

[3] Kenneth N. Fishell, "Utilization Patterns of Programed Materials in the Junior High School," Dissertation Abstracts, 1964, pp. 2881-2882.

[4] Robert A. Goldbeck and others, "Integrating Programed Instruction with Conventional Classroom Teaching," San Mateo, Calif.: American Institute for Research, 1962, as cited by Schramm, The Research on Programed Instruction, p. 55.

[5] Richard S. Hatch and Lanning L. Flint, "Programed Learning: A Comparative Evaluation of Student Performance Variables Under Combinations of Conventional and Automated Instruction," New York: U. S. Industries, Educational Sciences Division, 1962, as cited by Schramm, The Research on Programed Instruction, p. 60.

[6] Norman W. Sargent, "The Effects on Learning and Attitudes of Cumulatively Adding Three Instructional Techniques to Conventional Teaching in a Course in Audio-Visual Education," Dissertation Abstracts, 1964, pp. 5097-5098.

Methods of using programs in the schools are still to be specified.[1]

Importance of the Study

The claims surrounding programed instruction are conflicting. Advice as to the best method of combining programed instruction and conventional instruction is also conflicting. Though this study is concerned with but two of the many possible methods of combining programed instruction with conventional instruction, it should aid the Physical Science teachers of the Grand Forks Public Schools in sorting out some of the conflicting claims and advice.

Experimentation with programed materials is necessary to avoid costly mistakes in using such material and to make the maximum use of the material. It is the researcher's belief that each teacher must engage in such experimentation.

Need for Research in the Area

Active experimentation is needed before a school system adopts any instructional methodology on a large scale. Though a review of the research involving programed materials leads one to the conclusion that programed materials are effective, the research is too limited and too inconclusive to draw any conclusions as to the most effective method of utilizing programed materials.

A number of the characteristics of the learner have been studied to determine their relationship to the effectiveness of programed instruction. However, such studies have also been too limited

---

[1] Silberman, Programmed Learning and Computer=Based Instruction, p. 19.

and too inconclusive to draw any conclusions as to the student variables that are factors in the successful use of programed materials.

Definition of Terms

Application Score: The total score on those items of the criterion test which require the student to apply his knowledge to new or different situations than those presented in the textbook or programed material.

Constructed Response: A response which is chosen from a virtually unlimited number of alternatives, based on the student's past experience. The response, however, may be limited to a general type, such as words or numbers.

Conventional Instruction: An instructional methodology which has been prviously used by a teacher. It consists of a combination of lecture, recitation, laboratory exercises, textbook assignments, demonstrations, and quizzes.

Frame: A unit of a program. The segment displayed at each step in the sequence. Usually the unit that requires a response.

Linear Program: A program which has a single, predetermined sequence of steps. Error responses are not corrected or immediately repeated.

Pace: The rate at which the student is permitted to work through the programed material. The pace may be determined by the learner or by the experimenter.

Programed Book: A special book in which the subject matter to be learned has been arranged into a series of sequential steps leading from familiar concepts to new materials. Differs from a "scrambled textbook" in that the content is arranged so that the student proceeds directly from one step to the next.

Prompt: Some type of verbal or symbolic cue which facilitates the desired response from the student.

Recall Score: The total score on those items of the criterion test which require the student to recall or recognize the correct response to situations presented in the textbook and programed material.

Sequencing: Arranging the frames of a program in an order that provides the most efficient situation for learning.

Step: The increment in subject matter level to be learned with each succeeding item or frame in the program.

Terminal Behavior: The behavior a program is designed to produce.

CHAPTER II

REVIEW OF THE RELATED RESEARCH

In 1926, Sidney Pressey of Ohio State University developed a device that might be considered the prototype of all subsequent teaching machines. Pressey originally conceived of the machine as an automatic testing device. However, it soon became apparent that the machine also possessed instructional properties. Basically, Pressey's machine consisted of a device which displayed a multiple-choice question to the student. The student pressed a button corresponding to his choice of an answer. If his choice was correct, the machine presented the next question. If his choice was incorrect, the question remained and an error was tallied on a counter at the back of the device.

Pressey's device never caught on widely. Perhaps one of the reasons that it failed to do so was due to its intrinsic limitations. A. A. Lumsdaine states,

> One of these limitations is that, as a multiple-choice device, it appears to be limited to recognition responding rather than permitting the student to compose or construct his own response.[1]

Some years later, B. F. Skinner of Harvard University developed a device that employed a constructed-response program. Only one question

---

[1] A. A. Lumsdaine, "Teaching Machines: An Introductory Overview," Teaching Machines and Programmed Learning, ed. A. A. Lumsdaine and Robert Glaser (Washington, D.C.: National Education Association, 1960) p. 10.

at a time was visible to the student and he wrote his answer on an exposed portion of the frame. The student then raised a lever which exposed the correct answer and, at the same time, moved the answer the student had just written up under a transparent cover where he could see it, but could no longer change it. If the student decided that his answer was correct, he moved the lever over to the right. This marked his answer tape to show that he had scored himself correct on that question. Returning the lever to its original position brought the next question into view.

The Programed Textbook

One of the simpler devices that have been developed has been the programed textbook. Cost-wise, programed textbooks are attractive and research indicates that they are as effective as the so-called "teaching machines." For example, Silberman cites seven studies comparing a programed textbook to a teaching machine.[1] In six of the studies, no significant difference was found in the scores of the two groups on a criterion test. In the seventh study, students using the programed textbook scored significantly higher. In addition, students using programed textbooks required significantly less time in four of the studies.

---

[1] Harry F. Silberman, "Characteristics of Some Recent Studies of Instructional Methods," Programmed Learning and Computer=Based Instruction, ed. John E. Coulson (New York: John Wiley and Sons, Inc., 1962) p. 18

TABLE 1

STUDIES COMPARING A PROGRAMED TEXTBOOK TO A TEACHING MACHINE

Researcher	Sample	Program	Results
Alter Silverman[1]	60 college students	90 frames on binary numbers	No significant difference
Eigen[2]	72 high school students	Mathematics	No significant difference
Eigen and others[3]	77 eighth-grade students	65 frames on numbers and numerals	No significant difference
Eigen Komoski[4]	74 high school students	707 frames on mathematics	No significant difference
Gotkin Goldstein[5]	215 fourth-grade students	First 100 words of TMI spelling program	No significant difference
Holt Hammock[6]	63 telephone technicians	2600 frames on basic electricity	No significant difference
Hough Revsin[7]	90 college students	555 frames on Secondary School History	No significant difference
Smith Moore[8]	100 high school students	1036 frames on mathematics	No significant difference

[1] Millicent Alter and Robert Silverman, "The Response in Programed Instruction," Journal of Programed Instruction, 1, (1962), pp. 55-78.

[2] Lewis D. Eigen, "High School Student Reaction to Programed Instruction," Phi Delta Kappan, 44, (1963), pp. 282-285.

[3] Lewis D. Eigen and others, "A Comparison of Three Modes of Presenting a Programed Instruction Sequence," (New York: The Center for Programed Instruction, 1962), as cited by Wilbur Schramm, The Research on Programed Instruction, p. 39.

[4] Lewis D. Eigen and Kenneth P. Komoski, "Automated Teaching Project," (New York: Collegiate School, 1960), as cited by Wilbur Schramm, The Research on Programed Instruction, p. 39.

[5] Lassar G. Gotkin and Leo S. Goldstein, "Programed Instruction for the Younger Learners," (New York: The Center for Programed Instruction, 1962), as cited by Wilbur Schramm, The Research on Programed Instruction, p. 56.

[6] Howard O. Holt and Joseph Hammock, "Books as Teaching Machines: Some Data," Applied Programed Instruction, ed. Stuart Margulies and Lewis D. Eigen (New York: John Wiley and Sons, Inc., 1962), pp. 50-56.

[7] John B. Hough and Bernard Revsin, "Programed Instruction at the College Level: A Study of Several Factors Influencing Learning," Phi Delta Kappan, 44, 6 (1963), pp. 286-291.

[8] Wendell I. Smith and J. William Moore, "Programed Materials in Mathematics," undated, cited by Schramm, The Research On Programed Instruction, pp. 98-99.

In each of the eight studies listed in Table 1, part of the sample worked with a teaching machine while the remainder used a programed textbook. In each study, no significant difference was found between students using a programed textbook and students using a teaching machine. The results seem to indicate that any controversy over the vehicle by means of which programed material is presented is unwarranted. And, in fact, there has been little controversy.

Constructed-Response vs. Multiple-Choice

Although there has been little controversy regarding the vehicle by means of which the programed material is presented, the same cannot be said regarding the type of programed material to be used. According to Edward B. Fry, a major dichotomy appears to have developed in the field of programed instruction.[1] One faction, headed by B. F. Skinner, favors the constructed-response type of program while the second group, headed by Sidney Pressey, favors the multiple-choice type of program.

Skinner would structure the program so that the student, through his responses, is led step by step toward the desired goal. The structuring of wrong answers is avoided. Skinner feels that if the teaching steps are small and understandable, a poor student can learn the same thing as a good student, but it will take the poor student longer.

---

[1] Edward B. Fry, "Teaching Machine Dichotomy: Skinner vs. Pressey," Psychological Reports, 1960, 6, pp. 11-14.

Pressey is willing to allow some error. By permitting error, particularly more than one error per question, he feels that the spread and significance of the total score is increased. However, even Pressey emphasizes that the number of right responses should greatly exceed the number of wrong responses. The specific amount of error permitted is not mentioned.

Pressey places no stress on the small learning steps or on the order of presentation. His programs are designed to supplement the conventional textbook, whereas Skinner's programs are designed to replace the textbook.

As the studies in Table 2 indicate, groups of students using a multiple-choice type of program did not differ significantly from groups using a constructed-response type of program on the respective criterion tests. However, the groups using the multiple-choice type of program did tend to complete their programs in less time.

Programed Learning Principles

W. J. Carr sets forth the following principles of learning upon which programed instruction is based:

1. Learning takes place most rapidly if the student is actively engaged with the subject matter.

2. Learning is most effective if the student develops the skills and knowledge in a form which will readily generalize to the "real life" situation for which they are intended.

3. Learning takes place most rapidly if immediate "knowledge of results" is given for each response.

TABLE 2

STUDIES COMPARING MULTIPLE-CHOICE PROGRAMS
TO CONSTRUCTED-RESPONSE PROGRAMS

Researcher	Sample	Program	Results
Burton Goldbeck[1]	21 ninth-grade students	35 frames on animal characteristics	No significant difference
Coulson Silberman[2]	184 college students	56-104 frames on psychology	No significant difference
Evans and others[3]	60 college students	125 frames on symbolic logic	No significant difference
Fry[4]	153 ninth-grade students	Spanish vocabulary items	No significant difference
Hough[5]	41 college students	The Secondary School	No significant difference
Pressey[6]	120 college students	54 frames on psychology	No significant difference
Roe and others[7]	186 college students	230 frames on elementary probability	No significant difference

[1] Benjamin B. Burton and Robert A. Goldbeck, "The Effect of Response Characteristics and Multiple-Choice Alternatives on Learning During Programed Instruction," (San Mateo: American Institute for Research, 1962) as cited by Schramm, The Research on Programed Instruction, pp. 27-28.

[2] John E. Coulson and Harry F. Silberman, "Effects of Three Variables in a Teaching Machine," Journal of Educational Psychology, 51 (1960), pp. 135-143.

[3] James L. Evans, Robert Glaser, and Lloyd E. Homme, "An Investigation of 'Teaching Machine' Variables Using Learning Programs in Symbolic Logic," Journal of Educational Research, 55 (1962), pp. 433-452.

[4] Edward B. Fry, "A Study of Teaching Machine Response Modes," Teaching Machines and Programed Learning, pp. 469-474.

[5] John B. Hough, "An Analysis of the Efficiency and Effectiveness of Selected Aspects of Machine Instruction," Journal of Educational Research, 55 (1962), pp. 467-471.

[6] Sidney L. Pressey, "A Puncture of the Huge 'Programing" Boom?" (Tucson: undated), cited by Wilbur Schramm, The Research on Programed Instruction, p. 87.

[7] Arnold Roe, Mildred Massey, Gershon Weltman, and David Leeds, "Automated Teaching Methods Using Linear Programs," Journal of Psychology, 40 (1962), pp. 198-201.

4. Learning takes place most rapidly if the subject matter is organized in a hierarchic form.

5. Receiving frequent "knowledge of results" keeps students working at the assigned task.

6. Since learning takes place in individuals, the learning situation should be designed so that each student may proceed at his own pace.[1]

The group led by Skinner feels that the first two principles listed by Carr require an overt, constructed-response by the student. Yet, as shown in Table 2, programs in which the student merely selected the correct response have proven to be just as effective as programs requiring a constructed-response.

Overt Responding vs. Covert Responding

A number of studies have been made comparing overt responding (in which the student writes his response) to covert responding (in which the student merely reads the programed material). As Table 3 shows, no significant difference, as measured by a criterion test, was found between students reponding overtly and students responding covertly.

A study by Alter and Silverman found a significant difference in favor of covert responding.[2] The finding of Cummings and Goldstein,

---

[1] W. J. Carr, "A Review of the Literature on Certain Aspects of Automated Instruction," Programmed Learning, ed. Wendell I. Smith and J. William Moore (New York: D. Van Nostrand Company, Inc., 1962), pp. 57-80

[2] Millicent Alter and Robert Silverman, "The Response in Programed Instruction," Journal of Programed Instruction, 1, 1 (1962), pp. 55-78.

TABLE 3

STUDIES COMPARING OVERT RESPONDING TO COVERT RESPONDING

Researcher	Sample	Program	Results
Evans and others[1]	10 college students	50-60 frames on math and music	No significant difference
Krumboltz Weisman[2]	54 college students	177 frames on educational testing	No significant difference
Roe and others[3]	186 college students	230 frames on elementary probability	No significant difference
Hughes[4]	199 IBM trainees	719 frames on basic computer knowledge	No significant difference
Lambert Miller Wiley[5]	552 ninth-grade students	864 frames on sets, relations and functions	No significant difference
Stolurow Walker[6]	51 college students	Statistics	No significant difference

[1] James L. Evans, Robert Glaser, and Lloyd E. Homme, "An Investigation of Variation in the Properties of Verbal Learning Sequences of the 'Teaching Machine' Type," Teaching Machines and Programmed Learning, pp. 446-451.

[2] John D. Krumboltz and Ronald G. Weisman, "The Effect of Overt vs. Dovert Responding to Programed Instruction on Immediate and Delayed Retention," Journal of Educational Psychology, 53, 2 (1962), pp. 89-92.

[3] Arnold Roe, Mildred Massey, Gershon Weltman, and David Leeds, "Automated Teaching Methods Using Linear Programs," Journal of Psychology, 40 (1962), pp. 198-201.

[4] John L. Hughes, "Effect of Changes in Programed Text Format and Reduction of Classroom Time on the Achievement and Attitude of Industrial Trainees," Journal of Programed Instruction, 1, 1 (1962), pp. 43-54.

[5] Philip Lambert, Donald M. Miller, and David E. Wiley, "Experimental Folklore and Experimentation: The Study of Programed Learning in the Wauwatosa Public School," Journal of Educational Research, 55 (1962), pp. 485-494.

[6] L. M. Stolurow and C. C. Walker, "A Comparison of Overt and Covert Response in Programed Learning," Journal of Educational Research, 55 (1962), pp. 421-432.

on the other hand, favored overt responding.[1] Finally, a study by Goldbeck and Campbell found a significant difference in favor of covert responding on "easy" material, a significant difference in favor of overt responding on "average" material, and no significant difference on "difficult" material.[2]

It is likely, of course, that a student does construct a "mental" response, though he may not be required to write it. Nevertheless, research fails to support the view that an overt, constructed-response by the student is a necessity.

Knowledge of Results

It is also questionable whether the immediate "knowledge of results" is a necessity. Studies by Hough and Revsin[3], Moore and Smith[4], and Smith and Moore[5] found that there was no significant difference in the results on a post-test between students receiving no immediate knowledge of correct responses and students receiving such knowledge.

---

[1] Allana Cummings and Leo S. Goldstein, "The Effect of Overt and Covert Responding on Two Kinds of Learning Tasks," Educational Technology, ed. John P. DeCecco (New York: Holt, Rinehart and Winston, 1964), pp. 231-241.

[2] Robert A. Goldbeck and Vincent N. Campbell, "The Effects of Response Mode and Response Difficulty on Programed Learning," Journal of Educational Psychology, 53 (1962), pp. 110-118.

[3] John B. Hough and Bernard Revsin, "Programed Instruction at the College Level: A Study of Several Factors Influencing Learning," Phi Delta Kappan, 44, 6 (1963), pp. 286-291.

[4] J. William Moore and Wendell I. Smith, "Knowledge of Results in Self-Teaching Spelling," Psychological Reports, 9 (1961), pp. 717-726.

[5] Wendell I. Smith and J. William Moore, "A Comparison of Several Types of 'Immediate Reinforcement,'" (Air Force Office of Scientific Research), cited by Wilbur Schramm, The Research on Programed Instruction, pp. 84-85.

A study by Krumboltz and Weisman compared the following six groups: (1) Group 1 received no knowledge of what the correct responses were, (2) Group 2 was informed of the correct response on every third item, (3) Group 3 was informed of the correct response on two items out of every three, (4) Group 4 was informed of the correct response on all items, (5) Group 5 was informed of the correct response on 33 percent of the items chosen randomly, and (6) Group 6 was informed of the correct response on 67 percent of the items chosen randomly.[1] They found no significant difference between these groups in the results on a post-test.

Step Size

As was pointed out previously, the faction headed by Skinner favors the type of program in which the student proceeds toward the desired goal via a series of small steps. Research on step size has been limited and the results of the studies that have been made show disagreement. For example, studies by Coulson and Silberman[2] and Evans, Glaser, and Homme[3] found a significant difference in favor of

---

[1] John D. Krumboltz and Ronald G. Weisman, "The Effect of Intermittent Confirmation in Programed Instruction," Journal of Educational Psychology, 53, 6 (1962), pp. 250-253.

[2] John E. Coulson and Harry F. Silberman, "Effects of Three Variables in a Teaching Machine," Journal of Educational Psychology, 51 (1960), pp. 135-143.

[3] James L. Evans, Robert Glaser, and Lloyd E. Homme, "An Investigation of Variation in the Properties of Verbal Learning Sequences of the 'Teaching Machine' Type, Teaching Machines and Programed Learning, pp. 446-451.

small-step programs over large-step programs. In the latter study, programs of 30 frames, 40 frames, 51 frames, and 68 frames were used to teach a mathematics concept to college students. The 51-frame and the 60-frame programs were significantly better than the other two; the 51-frame program was slightly better than the 60-frame program.

Smith and Moore used programs of 1,128 frames, 830 frames, and 546 frames to teach the same spelling words to fifth graders.[1] They found no significant difference between the three groups of students on a post-test.

Sequencing of Programs

Studies comparing sequential programs with non-sequential programs have also been limited in number. Levin and Baker found no significant difference between a sequential program and a non-sequential program in the teaching of geometry to second graders.[2] Roe and Roe also found no significant difference between a sequential program and a non-sequential program in their study involving the teaching of a statistical concept to college freshmen.[3] Stolurow's study in which he

---

[1] Wendell Smith and J. William Moore, "Size-of-Step and Achievement in Programed Spelling," Programmed Learning, ed. Wendell I. Smith and J. William Moore (New York: D. Van Nostrand Company, Inc., 1962) pp. 202-206.

[2] Gerald R. Levin and Bruce L. Baker, "Item Scrambling in a Self-Instructional Program," Journal of Educational Psychology, 54, 3 (1963), pp. 138-143.

[3] Kiki V. Roe and A. Roe, "Scrambled vs. Ordered Sequence in Auto-Instructional Programs," Journal of Educational Psychology, 53 (1962), pp. 101-104.

used mentally retarded students also found no significant difference.[1] Stolurow did find a significant correlation between intelligence and post-test scores and between language ability and post-test scores for the group using the unorganized program.

Self-Pacing vs. External Pacing

Though it may be advantageous to the student if he is permitted to proceed through a program at his own pace, such self-pacing does create problems in the classroom. Table 4 indicates that self-pacing

TABLE 4

STUDIES COMPARING SELF-PACED GROUPS TO EXTERNALLY-PACED GROUPS

Researcher	Sample	Program	Results
Alter Silverman[2]	60 college students	87 frames on basic electricity	No significant difference
Carpenter Greenhill[3]	113 college students	2,055 frames on modern algebra	No significant difference
Moore Smith[4]	35 sixth-grade students	846 frames on spelling	No significant difference
Silverman Alter[5]	45 college students	87 frames on basic electricity	No significant difference

---

[1] Lawrence M. Stolurow, "Social Impact of Programmed Instruction: Aptitudes and Abilities Revisited," Educational Technology, pp. 348-355.

[2] Millicent Alter and Robert Silverman, "The Response in Programed Instruction," Journal of Programed Instruction, 1, (1962), pp. 55-78.

[3] C.R. Carpenter and L. P. Greenhill, Comparative Research on Methods and Media for Presenting Programed Courses in Mathematics and English, (University Park, Pa.: University Division of Instructional Services, The Pennsylvania State University, 1963).

[4] J. William Moore and Wendell I. Smith, "Knowledge of Results in Self-Teaching Spelling," Psychological Reports, 9 (1961), pp. 717-726.

[5] Robert E. Silverman and Millicent Alter, "Response Mode, Pacing, and Motivational Effects in Teaching Machines," (Port Washington, N.Y.: U.S. Naval Training Device Center, 1961), as cited by Wilbur Schramm, The Research on Programed Instruction, pp. 96-97.

is not a necessity. In all of the studies cited, no significant difference was found between self-paced groups and externally-paced groups. Apparently many students may be forced to work at a more rapid pace or, in some cases, at a slower pace without any harmful effect. Reducing the pace 20 percent or increasing the pace 10 percent, as was done in the Carpenter and Greenhill study, had no significant effect. Thus, an externally-paced program may be the answer to the problem of what to do with the students who complete a program in considerably less time than their classmates. External pacing would reduce this gap in time.

Intelligence and Programed Learning

As was noted in Chapter One, a number of characteristics of the learner have been studied to determine their relationship to the effectiveness of programed instruction. One of these characteristics or factors has been that of intelligence.

Of the ten studies shown in Table 5, seven indicate a significant correlation between intelligence and achievement using programed materials. The Reed and Hayman study, interestingly enough, also found that there was a significant difference in the achievement of low-ability students over that of high-ability students using conventional instruction. Will a combination of programed and conventional instruction, then, be more effective for both high- and low-ability students than conventional instruction or programed instruction alone?

TABLE 5

STUDIES OF THE CORRELATION BETWEEN INTELLIGENCE AND ACHIEVEMENT USING PROGRAMED MATERIALS

Researcher	Sample	Program	Results
Beane[1]	65 high school students	852-951 frames on mathematics	A significant correlation
Evans[2]	48 college students	Psychology	A significant correlation
Hatch Flint[3]	46 college students	3,478 frames on electronics	A significant correlation
Lambert and others[4]	552 ninth-grade students	864 frames on mathematics	A significant correlation
Northcutt[5]	8 classes of fifth-graders	13 days on spelling	A significant correlation
Smith[6]	195 fifth-grade students	757 frames on arithmetic	A significant correlation
Feldhusen Eigen[7]	96 high school students	Mathematics	No significant correlation
Fishell[8]	24-160 junior high school students	Five programs in mathematics and social science	No significant correlation
Branson[9]	Not given	Not given	No significant correlation
Reed Hayman[10]	250 tenth-grade students	2,600 frames on English grammar	A significant correlation

[1] Beane, loc. cit.

[2] Gary W. Evans, "Mode of Presentation, Pacing, Knowledge of Results, and Intellectual Level in Automated Instruction," Dissertation Abstracts, 1964, pp. 1317-1318.

[3] Richard S. Hatch and Lanning L. Flint, "Programed Learning: A Comparative Evaluation of Student Performance Variables Under Combinations of Conventional and Automated Instruction," (New York: U.S. Industries, Educational Sciences Division, 1962) as cited by Wilbur Schramm, The Research on Programed Instruction, p. 60.

[4] Philip Lambert, Donald M. Miller, and David E. Wiley, "Experimental Folklore and Experimentation: The Study of Programed Learning in the Wauwatosa Public Schools," Journal of Educational Research, 55 (1962), pp. 485-494.

[5] Mary P. Northcutt, "The Comparative Effectiveness of Classroom and Programed Instruction in the Teaching of Decimals to Fifth Grade Students," Dissertation Abstracts, 1964, pp. 5091-5092.

Other Student and Teacher Variables

The studies of Geller[1] and Branson[2] found that there was no significant correlation between reading ability and achievement using programed materials. Lankford's study, on the other hand, found a positive correlation.[3]

Feldhusen and Eigen found that a student's general achievement level was a better predictor of success using programed materials than was the student's score on an intelligence test.[4]

Of interest also is the study of Barcus, Hayman, and Johnson which found that the increase in learning of students using a programed textbook was directly proportional to the training of their teachers.[5]

---

[6] Leone M. Smith, "Programed Learning in Elementary School: An Experimental Study of Relationships Between Mental Abilities and Performance," (Urbana: University of Illinois, 1962), cited by Schramm, The Research on Programed Instruction, p. 98.

[7] John F. Feldhusen and Lewis D. Eigen, "Interrelationships Among Attitude, Achievement, Reading, Intelligence, and Transfer Variables in Programed Instruction," 1963, cited by Wilbur Schramm, The Research on Programed Instruction, pp. 42-43.

[8] Kenneth N. Fishell, "Utilization Patterns of Programed Materials in the Junior High School," Dissertation Abstracts, 1964, pp. 2881-2882.

[9] Robert K. Branson, "Some Pitfalls in the Classroom Use of Programs," Trends in Programmed Instruction, pp. 78-79.

[10] Jerry E. Reed and John L. Hayman, Jr., "An Experiment Involving Use of English 2600, An Automated Instruction Text," Journal of Educational Research, 55 (1962), pp. 476-484.

[1] Geller, loc. cit.

[2] Branson, Trends in Programmed Instruction, pp. 78-79.

[3] Bethene C. Lankford, "Programmed Instruction in the Junior High School: A Study of Teacher Roles," Dissertation Abstracts, 1965, pp. 5791-5792.

[4] Feldhusen and Eigen, loc. cit.

[5] Delbert Barcus, John L. Hayman Jr., and James T. Johnson, "Programing Instruction in Elementary Spanish," Phi Delta Kappan, 44, 6 (1963), pp. 269-272.

A review of the research with programed materials leads one to the conclusion that programed materials are effective. However, the research is too limited and too inconclusive to draw any conclusions as to (1) the most effective method for utilizing programed materials, (2) the effect of teacher training, experience, and attitude on the success of students using programed materials, and (3) the student variables that are factors in the successful use of programed materials.

CHAPTER III

METHODOLOGY

The Sample

The study was conducted in the Grand Forks Public School System during the 1965-1966 school year. Twenty-three classes of ninth grade Physical Science students in three junior high schools took part. These 23 classes included all of the ninth graders in the school system.

Since the study began approximately mid-way in the school year, intact classroom units were used. The classes were randomly assigned to one of the three treatment groups.

The pre-test was written by 609 students. Of this group, 19 were lost to the study because of moving, extended illness, or inconsistent attendance, and 43 were lost because of the absense of standardized test scores. Thus, the study is limited to 547 students.

The Measuring Instruments

In addition to the criterion test, which will be described later in this chapter, the Iowa Test of Educational Development and the California Test of Mental Maturity were used. The Iowa Test of Educational Development, which was administered to the ninth graders in the fall of 1965, provided background information relative to achievement in mathematics, achievement in the reading of natural science materials, and general achievement level. Standard scores were used. The California Test of Mental Maturity, which was administered to the students in 1963, provided the intelligence quotient.

The Treatment Groups

As was stated previously, each classroom unit was randomly assigned to one of three treatment groups. The three groups are referred to in this report as the Introductory Group, the Review Group, and the Conventional Group.

Students in the Introductory Group used the programed material as initiatory assignments. They worked with the material in the classroom and under the supervision of the teacher. The students were allowed about 30 minutes to complete the part of the program assigned and the answer sheets were collected at the conclusion of the 30 minute period. The teacher was free to use the remaining portion of the class period or periods for discussion, lecture, demonstrations and/or any other instructional technique that the teacher felt would aid the students.

Basically, the unit was divided into 12 rather lengthy assignments. Students in the Introductory Group used a part of the program as an introduction to each assignment. Use of the programed material was not restricted to the first half of a class period nor to a single sitting. The only restriction on the use of the programed material was that it be used as the students' initial contact with an assignment.

Students in the Review Group used the programed material as review assignments. They worked with the material in the classroom and under the supervision of the teacher whenever possible. However, when necessary, the review assignments were completed by the students as homework. The answer sheets were turned in at the beginning of the next day's class period. The student's initial and developmental contacts with an assignment were made through conventional techniques--discussion, lecture, demonstrations and/or any other instructional technique that the teacher desired to use. The only restriction on the use of the programed material was that it be used only to review the concepts that were introduced and developed via other techniques. Since the Review Group spent no more time on the unit than did the other two groups, it was necessary to shorten the developmental phase of each assignment somewhat.

Students in the Conventional Group were assigned reading material from the textbook. The teachers were free to use any instructional technique that they felt would aid the students during class periods. It was assumed that the instructional technique or techniques used would be the same as those used in previous years.

Laboratory exercises were the same for all students. No attempt was made to measure the outcomes of laboratory learning except for such learning that was included as part of the content of the textbook or programed material.

The teachers taking part in the study were requested to maintain a log of the activities that transpired during each class period. The log was to include the time devoted to the use of the programed material, the laboratory and demonstration exercises performed, audiovisual materials used, and the topics or questions discussed. However, only one of the teachers kept such a log. Generally, the logs were limited to a record of the time devoted to programed material during a given class period.

The Research Design

A two-way analysis of covariance was used to test the null hypotheses previously cited. A 3 X 5 treatments by levels experimental design, discussed in Lindquist[1], Winer[2], and Walker and Lev[3], was used. The three instructional methods were the treatments and the five teachers were the levels.

In all analyses, the gain score was adjusted using five variables--pre-test score, intelligence quotient, standard score on the reading test of natural science material, standard score on the mathematics test, and the standard score for general achievement--as concomitant variables. One analysis was based on the total gain score. A second analysis was based on the recall gain score. Finally, a third analysis was based on the application gain score. Since it was necessary to use intact classroom groups in the study, the analyses were made using the unweighted subgroup means.

There are two kinds of error possible in testing any statistical hypothesis. The first, sometimes called a Type I error, is the

---

[1] E. F. Lindquist, Design and Analysis of Experiments in Psychology and Education, (Boston: Houghton Mifflin Company, 1953).

[2] B. J. Winer, Statistical Principles in Experimental Design, (New York: McGraw-Hill Book Company, 1962).

[3] Helen M. Walker and Joseph Lev, Statistical Inference, (New York: Holt, Rinehart and Winston, 1953).

error of rejecting an hypothesis when it is true. The second, a Type II error, is the error of retaining an hypothesis when it is false. In his discussion of the relative importance of the two types of error, Lindquist states,

> If a Type I error is made in the exploratory experiment, that is, if a "significant" result leads to a _false_ conclusion that Y is a factor of X, the likely consequences is that time and effort will be wasted on further experiments designed to determine the nature of the relationship between Y and X. To minimize the danger of thus following a false lead, we usually set a high level of significance for tests made in exploratory experiments.
>
> If we make a Type II error in the exploratory experiment, that is, if the null hypothesis is false, but we fail to get a significant result and therefore falsely conclude that Y is not a factor, the likely consequence is simply that we will fail to follow up a true lead. In a sense this is not as serious as to have wasted time following up a false lead, since in the meantime we may be trying out other possible leads, all of which might eventually have to be tried anyway. Furthermore, it will be generally understood that we have not _proved_ that Y is not a factor, so that anyone else who has his own reasons to believe that Y is a factor is at liberty to plan experiments to prove his contentions.[1]

Since the results of this study will provide the basis for further experimentation, by the researcher, it was important that the results were sound. Thus, the study is of an exploratory nature. Upon the recommendation of Lindquist and following the precedent set in previous studies of a similar nature, two high levels of significance were used--.01 and .05.

Collection of the Data

The criterion test (Appendix A) was administered as the pretest prior to beginning the study. The programed material and directions relative to its use were delivered to each teacher prior to the

---

[1] E. F. Lindquist, _Design and Analysis of Experiments in Psychology and Education_, p. 68.

administration of the pre-test. An attempt had been made to hold a couple of group meetings with the teachers, but the attempt met with limited success. One of the teachers involved in the study was an assistant coach and could not attend after-school meetings. A second taught an out-of-town, late afternoon extension class. A third served on the local NDEA salary committee which was holding frequent meetings at this time. Thus, contacts between teachers and the researcher were, of necessity, limited to personal contacts. The directions enclosed with the programed materials appear in Appendix B.

Background information on the students was gathered by the researcher while the study was in progress. This information included intelligence quotients and the standard scores on the quantitative, science reading, and composite parts of the Iowa Test of Educational Development.

Time devoted to the unit varied from 22 days to 30 days. This includes two days devoted to the pre- and post-tests. The longer period of time can be accounted for somewhat by the fact that a severe blizzard necessitated the closing of school for three days. Two of the teachers found it necessary to review some of the subject matter that had been covered prior to the blizzard. The other three teachers had reached the post-test stage when the blizzard struck. They needed but one extra day for review purposes.

The time devoted by each teacher to various aspects of the unit is tabulated in Table 6. The percentage of the total time spent by the students in the Introductory and Review Groups in the use of the programed material varied from 16.4 percent to 30.0 percent. Teacher A used a

TABLE 6

UTILIZATION OF TIME

	Teachers				
	A	B	C	D	E
Total number of minutes spent on the unit*	1100	1250	1100	1500	1200
Percentage of time spent using programed material	16.4	20.9	27.3	24.0	30.0
Percentage of time spent on testing	20.5	22.0	13.2	16.3	14.6
Percentage of time spent on laboratory activities	0.0	16.0	0.0	16.7	12.5

* Class periods were 50 minutes in length

different approach than did the other teachers in the use of the programed material, particularly in the case of the Introductory Group. Each new assignment was begun during the final fifteen minutes of a class period. Students were to complete the assignment as homework. The following class period would begin with a discussion of the assignment. The other teachers devoted more class time to the use of the programed material.

On the final day of the study, the criterion test was administered as the post-test. Students using the programed material were also asked to complete a short questionnaire to determine their reactions to the material.

Unit Objectives

Once the decision had been made relative to the unit to be programed for this study, it became necessary to prepare a list of the objectives or goals to be reached at the conclusion of the unit. The researcher, following consultation with the chairman of the Physical

Science Department of the Grand Forks Public School System, prepared such a list. And, following the suggestion of Robert F. Mager[1], the objectives were stated in behaviorial terms; in terms of the behavior the learner was to be able to demonstrate.

The objectives for the unit on "Matter, Atoms, and Molecules" were as follows:

The student shall, upon completion of the unit, be able to

1. Recall and/or recognize the correct definition of the following:

(1) atom
(2) atomic number
(3) atomic weight
(4) chemical change
(5) chemical property
(6) compound
(7) concentrated solution
(8) density
(9) diffusion
(10) dilute solution
(11) electrolysis
(12) electron
(13) element
(14) emulsion
(15) gas
(16) Kinetic Theory
(17) Law of Conservation of Matter
(18) Law of Definite Proportions
(19) liquid
(20) matter
(21) mixture
(22) molecule
(23) neutron
(24) nucleus
(25) period
(26) physical change
(27) physical property
(28) properties
(29) proton
(30) radical
(31) saturated solution
(32) solid
(33) solute
(34) solution
(35) solvent
(36) sublimation
(37) unsaturated solution
(38) valence number

2. Recall and/or recognize examples of:

(1) chemical change
(2) chemical properties
(3) physical change
(4) physical properties

3. Recall and/or recognize the symbols of the elements listed in the chart on page 28 of the textbook, *Modern Physical Science*.

---

[1] Robert F. Mager, *Preparing Objectives for Programed Instruction*, (San Francisco: Fearon Publishers, 1962).

excepting antimony and arsenic, and the radicals listed in the chart on page 31 of the textbook, excepting acetate, bicarbonate, chlorate, phosphate, and sulfite.

4. Determine the number of neutrons in an atom given the atomic weight and atomic number.

5. Determine, when given the formula of a compound, the number of elements present in the compound and the number of atoms of each element present.

6. Determine, using the crystal test, whether a solution is saturated or unsaturated.

7. Balance simple chemical equations.

8. Compute the density of a substance given the weight and volume of the substance.

9. Name the simple binary compounds when given their formulas.

10. Write the formula of a binary compound when given the valence numbers and names of the combining atoms and/or radicals and the formulas of water and sodium chloride.

11. Determine, when given the number of protons, neutrons, and electrons in an atom, the

(1) atomic number
(2) atomic weight
(3) valence number
(4) position of the atom in the Periodic Table
(5) the distribution of electrons in the energy levels

12. Determine the valence number of an element in a binary compound when given the valence number of the other element and the formula of the compound.

13. Use the Law of Definite Proportions, when given an example,

to determine the combining ratio of the two elements.

14. Recall and/or recognize and/or apply to new situations the following principles or facts:

(1) Atoms have an equal number of protons and electrons.
(2) Molecules move most rapidly in gases as compared to solids and liquids and an increase in the temperature of the gas causes the molecules to move more rapidly.
(3) The solubility of a gas in a liquid is inversely proportional to the temperature of the liquid and directly proportional to the pressure exerted on the solution.
(4) The solubility of a solid in a liquid increases as the temperature of the liquid increases and it is very slightly effected by changes in pressure.
(5) That the symbol △ is used in chemical equations as a shorthand expression for heat.
(6) The first scientific atomic theory was proposed in 1803 by John Dalton.

15. List the maximum number of electrons that can be present in the first three energy levels of an atom.

The Criterion Test

Using the unit objectives as the guide, a criterion test was prepared by the researcher. The test can be found in Appendix A. The criterion test items came from the researcher's personal file of test items. Many, if not all, of the items originally appeared in test booklets that accompanied General Science and Physical Science textbooks. No attempt was made to determine the source of the items.

The criterion test was composed of the following parts:

1. Part I: Fifteen multiple-choice items calling for the recognition of information presented in the programed material and textbook.

2. Part II: Fifteen constructed-response items calling for the recall of information presented in the programed material and textbook.

3. Part III: Fifteen multiple-choice items calling for the application of information presented in the programed material and textbook.

4. Part IV: Fifteen constructed-response items calling for application of information presented in the programed material and textbook.

The final draft of the criterion test was shown to two of the teachers taking part in the study. It was their opinion that the sampling was adequate and that the difficulty level of the items was comparable to items that they would use if they were to prepare their own test.

In the remainder of this report, Parts I and II above have been combined and are referred to as the Recall Test; Parts III and IV have also been combined and are referred to as the Application Test. An analysis of the responses on the multiple-choice items as compared to those on the constructed-response items was not made.

Reliability of the Criterion Test

A pre-trial check of the criterion test's reliability was not made. Data in the researcher's personal file of test items indicated that the reliability coefficient would be .60 or higher. However, since this data was based on the previous use of only 75 percent of the test items, the .60 figure, at best, represented an educated guess.

The Kuder-Richardson formula #20 and the post-test data were used to estimate the reliability coefficients of the Recall Test, the Application Test, and the Total Test. These coefficients plus the mean and variance are shown for the three tests in Table 7.

TABLE 7

RELIABILITY COEFFICIENTS, MEANS, AND VARIANCES OF THE RECALL TEST, APPLICATION TEST, AND TOTAL TEST

Test	Number of test items	Mean	Variance	Reliability Coefficient
Recall Test	30	19.04	39.47	.889
Application Test	30	17.76	40.71	.873
Total Test	60	36.80	147.92	.936

Henry E. Garrett states that a reliability coefficient of .50 or .60 would be acceptable for a test designed to distinguish between the means of two groups of students.[1] As Table 7 indicates, the reliability coefficients of the Recall Test, the Application Test, and the Total Test were considerably higher than the minimum recommended by Garrett.

Conversion of the reliability coefficients into Fisher's z functions and computation of the standard error of these functions lead to the same standard error, .043, for each of the tests. Determination of the .95 and .99 confidence intervals for the true z's and the conversion of these z's back into r's gave the following confidence intervals for the reliability coefficients of the three tests:

TABLE 8

CONFIDENCE INTERVALS OF THE RELIABILITY COEFFICIENTS FOR THE RECALL TEST, APPLICATION TEST, AND TOTAL TEST

Test	.95 Confidence Interval	.99 Confidence Interval
Recall Test	.87 to .905	.865 to .91
Application Test	.85 to .89	.84 to .895
Total Test	.925 to .945	.920 to .948

The fiduciary probability is .95 that the true reliability coefficient of the Total Test lies within the interval, .925 to .945, and .05 that it falls outside of these limits. Likewise, the probability is .99 that the true reliability coefficient lies within the interval, .920 to .948, and .01 that it falls outside of these limits.

George A. Ferguson cautions that,

> Although substantive evidence is lacking, it is probable that in many experiments the measurements are less reliable under the experimental than under the control conditions, one of the effects of the treatment being to increase measurement error.[1]

To determine whether this had occurred in this study, the Kuder-Richardson formula #20 and the post-test data were used to find the estimated coefficient of reliability of the three tests for each of the treatment groups. Table 9 presents the estimated reliability coefficients, the means, and the variances of the three tests for each of the treatment groups.

TABLE 9

RELIABILITY COEFFICIENTS, MEANS, AND VARIANCES OF THE THREE TESTS FOR EACH OF THE TREATMENTS

Treatment Group	Recall Test	Application Test	Total Test
Conventional			
Mean....................	17.77	17.28	35.06
Variance...............	40.47	35.78	149.98
Reliability coefficient	.887	.849	.934
Introductory			
Mean....................	19.14	17.50	36.64
Variance...............	43.75	47.59	169.25
Reliability coefficient	.906	.895	.946
Review			
Mean....................	20.15	18.47	38.62
Variance...............	34.31	37.80	129.24
Reliability coefficient	.874	.868	.928

---

[1] George A. Ferguson, Statistical Analysis in Psychology and Education, (New York: McGraw-Hill Book Company, Inc., 1959), p. 288.

The estimated reliability coefficients of each of the three tests were higher for the Introductory Group than for either of the other two groups. However, although the reliability coefficients varied for the three treatment groups, the differences were not significant statistically.

No correction for chance guessing was made in the scores on the multiple-choice parts of the test since the students were not directed to avoid guessing and since sufficient time was allowed for completing the test. To be accepted as correct, a constructed-response had to be correctly spelled or, in the case of formulas, the subscripts and parentheses had to be correctly positioned.

Appendix C presents further data on the pre- and post-tests. It shows the number and percentage of students answering each test item correctly on the pre-test, the number and percentage of students answering each test item correctly on the post-test, and the gain in terms of correct responses. It also indicates the number of students in each treatment group who responded correctly to the various test items.

Validity of the Criterion Test

The validity of a test is dependent upon its function. There is no one validity because the same test may be used for different purposes. In this study, the primary concern was for the content and concurrent validity.

In the words of Fred N. Kerlinger,

> Content validity is the representativeness or sampling adequacy of the content--the substance, the matter, the topics--of a measuring instrument. Content validation is guided by the question: Is the

> substance or content of this measure representative of the content or the universe of content of the property being measured?[1]

Universes of content generally exist in theory only. Thus, to draw random samples of items from such a universe is not possible. One must rely on judgment as to whether the items are representative.

Sixty-five specific objectives were set forth for the unit, "Matter, Atoms, and Molecules." The criterion test evaluated student performance on 60 of these objectives. In the judgment of three of the teachers taking part in this study, the sampling was adequate. Of the remaining two teachers, one felt that the test over-emphasized the distribution of electrons in the energy levels, while the second felt that the test under-emphasized formulas and equations. It should be pointed out that none of the teachers, on a unit involving as many class periods as this particular unit involved, were in the habit of evaluating student performance by the use of a single test. Generally, the evaluation was made using two or three spaced tests. Obviously, sampling could be quite thorough in such a case.

Concurrent validity is characterized by checking a measuring instrument against some outside criterion. The criterion chosen for this study was the student's course grade in physical science at the time the study was begun. In other words, student performance as evaluated by the criterion test was to correlate significantly with student performance as evaluated by the teachers prior to the study. Though the grading practices of the individual teachers varied, it was the feeling

---

[1] Fred N. Kerlinger, Foundations of Behavioral Research, (New York: Holt, Rinehart and Winston, Inc., 1965), pp. 445-446.

of the researcher that the evaluation of student performance by the criterion test should be closely related to the evaluation of student performance by the teacher.

The product-moment method for determining correlation was used to find the correlation between the criterion test and teachers' grades. It was found that the correlation between the Recall Test and teachers' grades was .774; between the Application Test and teachers' grades, .795; and between the Total Test and teachers' grades, .822. In all cases, the correlation was statistically significant.

The Programed Material

The programed material for the unit, "Matter, Atoms, and Molecules," was based upon the content of Chapters Two and Three of Modern Physical Science (1962), published by Holt, Rinehart and Winston, Inc. A linear program was prepared by the researcher. The first trial of the program, using a junior high school student as the subject, resulted in errors on 9.2 percent of the total possible responses. Revision of the program and a second trial, using a second junior high school student, reduced the errors to 5.7 percent of the possible responses. The program was revised a second time and the third trial, using a third junior high school student, resulted in errors on 3.5 percent of the responses. No further revisions were made since the percentage of error was considered to be sufficiently small.

Using the time required by the third trial subject as a guide, the program was divided into twelve approximately equal parts. It was estimated that the average student could complete each part in 25 to 35 minutes.

The content of the twelve parts of the program is summarized below:

Part 1: Definition of Matter
States of Matter
Changing States
Sublimation

Part 2: Physical and Chemical Changes
Physical and Chemical Properties
Density

Part 3: Elements, Compounds, and Mixtures
Atoms and Molecules
Electrolysis

Part 4: Chemical Symbols[1]

Part 5: Chemical Symbols[1]

Part 6: Formulas and Equations
Law of Conservation of Matter
Law of Definite Proportions

Part 7: Solutions, Solutes, and Solvents
Saturated and Unsaturated Solutions
Solubility of Gases and Solids
Emulsions
Dilute and Concentrated Solutions

Part 8: The Atomic Theory
Electrons, Protons, and Neutrons

Part 9: Atomic Number
Atomic Charge
Atomic Weight

Part 10: Energy Levels
Orbitals

Part 11: The Periodic Table
Periods and Groups
Ions

---

[1] Material from *Chemical Symbols*, Programmed Unit in Chemistry by Virginia Powell (c) 1965 by Prentice-Hall, Inc., Englewood Cliffs, N.J. Reprinted with permission.

Part 12: Valence Numbers
Radicals
The Kinetic Theory
Diffusion

The program was the researcher's initial effort in the preparation of such material. Much use was made of what the researcher defines as "copying frames"--frames in which a definition was presented, followed by an example, and concluding with the student's use of the defined term as his response. Susan Meyer Markle feels that "copying frames" should never be used. However, she defines a copying frame as a

> ...frame in which the student is asked to copy a word or set of words that he could perfectly well produce without a model.[1]

It is questionable whether the students could have produced the scientific terms introduced in the program without first having been presented the model. As an introductory unit to the field of chemistry, the program emphasized new terms and their definitions.

The Dolch Test was used to compare the readability of the program and the textbook. The long sentence grade difficulty in both cases was Grade 4. The percent of hard words, words not appearing in the First Thousand Words for Children's Reading[2], was 32 percent in the case of the program and 30 percent in the case of the textbook. These are comparable figures.

---

[1] Susan Meyer Markle, Good Frames and Bad: A Grammar of Frame Writing, (New York: John Wiley and Sons, Inc., 1964), p. 192.

[2] E. W. Dolch, Problems in Reading, (Champaign, Ill.: The Garrard Press, Publishers, 1954).

No attempt was made in this study to analyze the students' response sheets to determine the strengths and weaknesses of the programed material.

The program, as used in the study, appears in Appendix D. In its final form, the program consisted of 619 frames calling for 835 responses.

CHAPTER IV

TREATMENT OF DATA

The findings of the study will be presented in the following seven parts:

1. Zero-Order Correlations
2. Regression Equations
3. Homogeneity of Variances
4. Analysis of Variance
5. Analysis of Covariance
6. Student Reaction to Programed Material
7. Teacher Data

Zero-Order Correlations

Table 10 presents the zero-order correlations between the predictor variables and the post tests, the gain scores, and the course grades. For an N of 547, a correlation coefficient of .088 is significant at the .05 level of confidence and a correlation coefficient of .115 is significant at the .01 level of confidence.[1] All of the correlation coefficients in Table 10 are significant at the .01 level of confidence with the exception of the correlation between the Application Pre-Test Scores and the Application Gain Scores.

---

[1] Henry E. Garrett, Statistics in Psychology and Education, p. 201.

TABLE 10

ZERO-ORDER CORRELATIONS BETWEEN THE PREDICTOR VARIABLES AND THE POST TESTS, THE GAIN SCORES, AND THE COURSE GRADES

	Q	SR	C	IQ	R1	A1	T1
Recall Post Test	.613	.597	.748	.550	.577	.529	.622
Application Post Test	.672	.646	.764	.601	.567	.540	.622
Total Post Test	.673	.652	.793	.603	.600	.560	.652
Recall Gain Score	.456	.440	.552	.402	.128	XXX	XXX
Application Gain Score	.472	.433	.534	.447	XXX	.031	XXX
Total Gain Score	.519	.488	.607	.473	.252	.185	.244
Course Grade	.689	.661	.786	.625	.586	.550	.638

Q = ITED Quantitative Standard Score
SR = ITED Science Reading Standard Score
C = ITED Composite Standard Score
IQ = CTMM Intelligence Quotient
R1 = Pre-Test, Recall
A1 = Pre-Test, Application
T1 = Pre-Test, Total

The best single predictor of achievement, as measured by the post test scores or the gain scores, was the ITED Composite Score. It was also the best single predictor of achievement, as measured by the course grade. The second best single predictor of achievement, as measured by the gain scores, was the ITED Quantitative Score.

The hypotheses of no significant correlation between the predictor variables and the Recall Gain Score, the Application Gain Score, and the Total Gain Score must be rejected. In each case, the correlation was significant. The significant correlation between intelligence, as measured by the CTMM, and achievement, as measured by the three gain scores, corroborates the findings of seven of the studies cited in Table 5 of Chapter Two. The findings also corroborates the finding of Feldhusen and Eigen, namely that a student's general achievement level is a better predictor of success using programed material than is the student's score on an intelligence test.

The zero-order correlations between the predictor variables and the three gain scores for each treatment group are found in Table 11. As can be noted, the correlations between the ITED scores (Quantitative, Science Reading, and Composite) and the gain scores were highest for the Introductory Group and lowest for the Review Group. The correlations between the CTMM Intelligence Quotients and the gain scores were highest for the Introductory Group and lowest for the Conventional Group. Correlations between the Recall Pre-Test scores and the gain scores were highest in the Conventional Group and lowest in the Review Group. This was also true of the correlations between the Application Pre-Test and Recall Gain scores and between the Total Pre-Test and Recall Gain scores.

Each coefficient of correlation, r, was converted into Fisher's z function. The standard error of the difference between two z's was determined using the formula,

$$SE_D = \sqrt{\frac{1}{N_1 - 3} + \frac{1}{N_2 - 3}}$$

in which N_1 and N_2 are the sizes of the two samples. Division of the actual difference between two z's by the SE_D resulted in a CR (critical ratio) which was compared to 1.96 and 2.58. The former is the CR which is significant at the .05 level of confidence, while the latter is significant at the .01 level of confidence.

TABLE 11

ZERO-ORDER CORRELATIONS BETWEEN THE PREDICTOR VARIABLES AND THE GAIN SCORES FOR EACH TREATMENT GROUP

	Recall Gain Score	Application Gain Score	Total Gain Score
ITED QUANTITATIVE			
Conventional...........	.450	.441	.503
Introductory...........	.574 **	.562 *	.624 *
Review................	.308	.392	.394
ITED SCIENCE READING			
Conventional...........	.445	.407	.483
Introductory...........	.500	.520	.561
Review................	.362	.370	.411
ITED COMPOSITE			
Conventional...........	.572	.524	.615
Introductory...........	.615 *	.600	.668 *
Review................	.436	.468	.508
CTMM INTELLIGENCE			
Conventional...........	.309	.352	.374
Introductory...........	.522 * #	.539 #	.583 * #
Review................	.349	.414	.429
RECALL PRE-TEST			
Conventional...........	.165	XXX	.303
Introductory...........	.164	XXX	.286
Review................	.041 ns	XXX	.159
APPLICATION PRE-TEST			
Conventional...........	XXX	-.004 ns	.220
Introductory...........	XXX	.121 ns	.264
Review................	XXX	-.026 ns	.076 ns
TOTAL PRE-TEST			
Conventional...........	.318 *	.216	.304
Introductory...........	.300	.259	.306
Review................	.121 ns	.104 ns	.126 ns

Conventional Group..... N = 176
Introductory Group..... N = 186
Review Group........... N = 185

* Significantly higher than that of the Review Group at the .05 level of confidence.

** Significantly higher than that of the Review Group at the .01 level of confidence.

\# Significantly higher than that of the Conventional Group at the .05 level of confidence.

ns Not significant

The correlations for the Introductory Group that were significantly higher than those for the Review Group included those between:

1. The Recall Gain Score and the ITED Quantitative Score.
2. The Application Gain Score and the ITED Quantitative Score.
3. The Total Gain Score and the ITED Quantitative Score.
4. The Recall Gain Score and the ITED Composite Score.
5. The Total Gain Score and the ITED Composite Score.
6. The Recall Gain Score and the CTMM Intelligence Quotient.
7. The Total Gain Score and the CTMM Intelligence Quotient.

The correlations for the Introductory Group that were significantly higher those for the Conventional Group included those between:

1. The Recall Gain Score and the CTMM Intelligence Quotient.
2. The Application Gain Score and the CTMM Intelligence Quotient.
3. The Total Gain Score and the CTMM Intelligence Quotient.

The zero-order correlations between the three gain scores and the ITED Quantitative Score, the ITED Science Reading Score, the ITED Composite Score, and the CTMM Intelligence Quotient were significant at the .01 level of confidence for all treatment groups. The correlation between the Recall Gain Score and the Recall Pre-Test Score was significant at the .05 level of confidence for the Conventional Group and the Introductory Group. It was not significant for the Review Group. The correlation between the Application Gain Score and the Application Pre-Test Score was not significant for any of the treatment groups. The correlation between the Total Gain Score and the Total Pre-Test Score was significant at the .01 level of confidence for the Conventional Group and the Introductory Group. It was not significant for the

Review Group.

In summary, the ITED and CTMM scores were better predictors of achievement, as measured by the three gain scores, for the Introductory Group than they were for the other two groups. The Pre-Test scores were the poorest single predictor of achievement.

Multiple Regression Coefficients

The correlation coefficients of the independent or predictor variables were used to predict or estimate a score for each of the dependent variables, the gain scores. With *k* variables, the multiple regression equation in raw-score form is

$$Y' = B_1X_1 + B_2X_2 + \ldots + B_kX_k + A$$

in which Y' represents the predicted or estimated gain score, B represents the partial regression coefficient, X represents the score on a predictor variable, and A is a constant. The constant, A, is given by

$$A = \overline{Y} - B_1\overline{X}_1 - B_2\overline{X}_2 - \ldots - B_k\overline{X}_k$$

The contribution of the various predictor variables to a multiple correlation and coefficient of determination with the Recall Gain Score is shown in Table 12.

R^2 is known as the coefficient of determination. It represents the proportion of the variance of the Recall Gain Score which is accounted for by the respective predictor variables. For example, 38.1 percent of the variance of the Recall Gain Scores was accounted for by three variables, the ITED Composite Score, the Recall Pre-Test Score, and the ITED Science Reading Score. The addition of predictor variable #4, the CTMM Intelligence, and predictor variable #5, the ITED Quantitative Score,

TABLE 12

CONTRIBUTION OF THE PREDICTOR VARIABLES TO A MULTIPLE CORRELATION AND COEFFICIENT OF DETERMINATION WITH THE RECALL GAIN SCORE

Predictors	Coefficient of Correlation (R)	Coefficient of Determination (R^2)
R: 1 2 3 4 5	.618	.382
R: 1 2 3 4	.618	.382
R: 1 2 3	.617	.381
R: 1 2	.614	.377
R: 1	.552	.305

R = Recall Gain Score
1 = ITED Composite Standard Score
2 = Recall Pre-Test Score
3 = ITED Science Reading Standard Score
4 = CTMM Intelligence Quotient
5 = ITED Quantitative Standard Score

increased the percentage of the variance accounted for to only 38.2 percent.

The ITED Composite Score accounted for 30.5 percent of the variance of the Recall Gain Scores. The Recall Pre-Test Score accounted for (37.7 - 30.5) or 7.2 percent of the variance and the ITED Science Reading Score for (38.1 - 37.7) or 0.4 percent. The CTMM Intelligence Quotient accounted for but 0.1 percent of the variance.

Though it seemed obvious that the ITED Quantitative Score and the CTMM Intelligence Quotient should not be included in the multiple regression equation, the researcher was not as positive about the ITED Science Reading Score. The inclusion of additional variables in the multiple regression equation always tends to reduce the error of estimate somewhat and leads to an increase in R. However, this increase in

R may not be statistically significant. To determine whether the increase in R possessed statistical significance, the following test was made

$$F = \frac{(R^2_1 - R^2_2)/(m_1 - m_2)}{(1 - R^2_1)/(N - m_1 - 1)}$$

in which

R_1 = the multiple based on m_1 independent variables
R_2 = the multiple based on m_2 independent variables selected from among the m_1 variables
N = the total number of cases

The results of the test appear in Table 13.

TABLE 13

A TEST OF THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN THE MULTIPLE CORRELATION COEFFICIENTS

Predictors	R^2	$R^2_1 - R^2_2$	$N - m_1 - 1$	F
R: 1 2 3 4 5	.382	.000	541	0.000
R: 1 2 3 4	.382	.001	542	0.877
R: 1 2 3	.381	.004	543	3.519
R: 1 2	.377	.072	544	62.610 **
R: 1	.305			

** Significant at the .01 level of confidence

Thus, the contribution of the ITED Science Reading Score was not significant. And the best combination of predictor variables for use in the multiple regression equation consists of but two of these variables, namely, the ITED Composite Score and the Recall Pre-Test Score.

The over-all regression equation, based on all of the data and disregarding the treatment subgroups, was

$$Y' = .76 X_1 - .58 X_2 + 4.02$$

in which, Y' = Predicted or Estimated Recall Gain Score
X_1 = ITED Composite Standard Score
X_2 = Recall Pre-Test Score

The contribution of the various predictor variables to a multiple correlation and coefficient of determination for the Application Gain Scores is shown in Table 14.

TABLE 14

CONTRIBUTION OF THE PREDICTOR VARIABLES TO A MULTIPLE CORRELATION AND COEFFICIENT OF DETERMINATION WITH THE APPLICATION GAIN SCORE

Predictors	Coefficient of Correlation (R)	Coefficient of Determination (R^2)
A: 1 2 3 4 5	.653	.426
A: 1 2 3 4	.652	.425
A: 1 2 3	.650	.422
A: 1 2	.647	.418
A: 1	.534	.285

A = Application Gain Score
1 = ITED Composite Standard Score
2 = Application Pre-Test Score
3 = CTMM Intelligence Quotient
4 = ITED Quantitative Standard Score
5 = ITED Science Reading Standard Score

The ITED Composite Score accounted for 28.5 percent of the variance in the Application Gain Scores. The Application Pre-Test accounted for (41.8 - 28.5) or 13.3 percent of the variance, the CTMM Intelligence Quotient for 0.4 percent, and the ITED Quantitative Score for 0.3 percent.

To determine whether the increases in R possessed statistical significance, the increases were tested using the F ratio shown on page 55. The results appear in Table 15.

The F test indicated that two predictor variables, the ITED Composite Score and the Application Pre-Test Score, should be included in the multiple regression equation based on all of the data. Thus, for all practical purposes, a combination of these two variables was as good

TABLE 15

A TEST OF THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN THE MULTIPLE CORRELATION COEFFICIENTS FOR THE APPLICATION GAIN SCORE

Predictors	R^2	$R^2_1 - R^2_2$	$N - m_1 - 1$	F
A: 1 2 3 4 5	.426	.001	541	0.943
A: 1 2 3 4	.425	.003	542	2.830
A: 1 2 3	.422	.004	543	3.775
A: 1 2	.418	.133	544	124.299 **
A: 1	.285			

** Significant at the .01 level of confidence

as a combination of all of the predictor variables. The multiple regression equation for the Application Gain Scores was

$$Y' = .83\ X_1 - .74\ X_2 + 3.571$$

in which, Y' = Predicted or Estimated Application Gain Score
X_1 = ITED Composite Standard Score
X_2 = Application Pre-Test Score

Homogeneity of Variances

One of the assumptions underlying the analysis of covariance is that the within-cell variations of both the covariates (the predictor variables) and criterion (the gain scores) are homogeneous. If they are homogeneous, the corresponding sources of variation may be pooled. One such test of the homogeneity of variance is the Hartley F-max test in which the ratio of the largest of the cell variances to the smallest of such variances is determined. However, because the results are difficult to interpret when the number of observations within cells varies greatly, as they do in this study, the researcher chose to use the Bartlett test. The Bartlett test utilizes the formula,

$$B = \frac{2.3026}{C}\left\{n(\log_{10} \Sigma n_i s^2_i - \log_{10} n) - \Sigma n_i \log_{10} s^2_i\right\}$$

in which

$$C = 1 + \frac{1}{3\ (14)} \left\{ \Sigma \frac{1}{n_i} - \frac{1}{n} \right\}$$

and n = observations within each subgroup
$n_i = n - 1$
s_i = variance within each subgroup

The statistic B has a chi-square distribution with k-1 or 14 degrees of freedom. The results of the Bartlett Test, Table 16, show that the hypothesis of homogeneity of variance must be rejected for the ITED Quantitative Score and the Pre-Test Scores. In the case of the ITED Quantitative Score, this result was unexpected since this score was given little weight in the assignment of students to the various class sections. Elimination of one subgroup, the Introductory Group of Teacher C, reduces the result to non-significance. This would indicate that fourteen of the subgroups were homogeneous with regard to the ITED Quantitative Score.

TABLE 16

BARTLETT TEST OF HOMOGENEITY OF VARIANCES

Variable	B
ITED Quantitative	24.48 *
ITED Science Reading	22.73
ITED Composite	19.78
CTMM Intelligence	20.06
Recall Pre-Test	29.55 **
Application Pre-Test	55.00 **
Total Pre-Test	57.52 **
Recall Gain Score	16.14
Application Gain Score	17.48
Total Gain Score	22.24

* Significant at the .05 level of confidence
** Significant at the .01 level of confidence

The heterogeneity of variance in the Pre-Test Scores was not as unexpected since intact classroom units were used in the study.

In addition, the students had received approximately one semester of instruction in Physical Science at the time the Pre-Tests were administered. Though the subject matter of the unit had not been covered directly, prior to the study, there is no doubt that some of it had been covered incidentally.

Of interest is the fact that the heterogeneity of variance of the Pre-Test Scores disappeared in the Post-Test Scores. Thus, the variance decreased following instruction.

Analysis of Variance--Recall Gain Scores

The summary of the within-cell information required for the analysis of variance of the Recall Gain Scores is shown in Table 17.

TABLE 17

THE NUMBER OF OBSERVATIONS, THE SUM OF THE RECALL GAIN SCORES, THE SUM OF THE RECALL GAIN SCORES SQUARED FOR EACH SUBGROUP

		Conventional Group	Introductory Group	Review Group	Total
Teacher A	n_{ij}	52	21	52	125
	ΣX	513	176	560	1,249
	ΣX^2	6,035	2,010	7,378	15,423
Teacher B	n_{ij}	28	42	17	87
	ΣX	282	367	174	823
	ΣX^2	3,572	4,071	2,136	9,779
Teacher C	n_{ij}	27	52	45	124
	ΣX	223	691	524	1,438
	ΣX^2	2,421	10,351	7,398	20,170
Teacher D	n_{ij}	40	51	21	112
	ΣX	214	483	205	902
	ΣX^2	1,626	6,189	2,347	10,162
Teacher E	n_{ij}	29	20	50	99
	ΣX	418	244	657	1,319
	ΣX^2	6,516	3,412	9,531	19,459
Total	n_{ij}	176	186	185	547
	ΣX	1,650	1,961	2,120	5,731
	ΣX^2	20,170	26,033	28,790	74,993

n_{ij} = number of observation
ΣX = sum of the Recall Gain Scores
ΣX^2 = sum of the Recall Gain Scores squared

Since the number of observations in each subgroup, or cell, varied, an unweighted-means analysis was made. The data in the cells of Part 1 of Table 18 are the means of the respective $\underline{n_{ij}}$ observations in the cells. The computational symbols in Part 2, Table 18, are based upon these means and the row and column totals of these means. In defining the computational symbols in Part 2, each of the cell means is considered as if it were a single observation. Computational formulas for the main effects and for interaction are given in Part 3.

TABLE 18

CELL MEANS, COMPUTATIONAL SYMBOLS, AND COMPUTATIONAL FORMULAS USED IN THE ANALYSIS OF THE RECALL GAIN SCORES

		Conventional Group	Introductory Group	Review Group	Total
	Teacher A	9.86	8.38	10.77	29.01
	Teacher B	10.07	8.62	10.24	28.93
(1)	Teacher C	8.26	13.29	11.64	33.19
	Teacher D	5.35	9.47	9.76	24.58
	Teacher E	14.41	12.20	13.14	39.75
	Total	47.95	51.96	55.55	155.46

(2)

(1) $G^2/pq = (155.46)^2/15 = 1611.19$

(2) $\Sigma X^2 = \quad = 74,993$

(3) $(\Sigma A^2_i)/q = (29.01^2 + \dots + 39.75^2)/3 = 1654.78$

(4) $(\Sigma B^2_j)/p = (47.95^2 + 51.96^2 + 55.55^2)/5 = 1616.97$

(5) $\Sigma(\overline{AB}_{ij})^2 = 9.86^2 + \dots + 13.14^2 = 1687.05$

(3)

$SS_A = \bar{n}_h \; (3) - (1) = 31.29 \; 1654.78 - 1611.19 = 1363.93$

$SS_B = \bar{n}_h \; (4) - (1) = 31.29 \; 1616.97 - 1611.19 = 180.86$

$SS_{AB} = \bar{n}_h \; (5) - (3) - (4) + (1) = 828.87$

The symbol, $\bar{n}_h$, represents the harmonic mean of the number of observations per cell and it is computed using the formula,

$$\bar{n}_h = \frac{pq}{\Sigma\Sigma(1/n_{ij})} = 31.29$$

In the computation of main effects and interactions, each cell is considered to have $\bar{n}_h$ or 31.29 observations. The harmonic mean is used rather than the arithmetic mean because the standard error of a mean is proportional to $1/n_{ij}$ rather than to n_{ij}.

The variation within each cell was found using the formula,

$$SS_{ij} = \Sigma X^2_{ij} - \frac{(\Sigma X_{ij})^2}{n_{ij}}$$

The pooled within-cell variation is

$$SS_W = \Sigma\Sigma SS_{ij}$$

The analysis of variance of the Recall Gain Scores is summarized in Table 19.

TABLE 19

ANALYSIS OF VARIANCE OF THE RECALL GAIN SCORES

Source of variation	SS	df	MS	F
A (teacher)	1,393.93	4	348.48	15.30 **
B (method)	180.86	2	90.43	3.97 *
AB (interaction)	828.87	8	103.61	4.55 **
Within cell	12,117.32	532	22.78	

* Significant at the .05 level of confidence
** Significant at the .01 level of confidence

The results of the analysis of variance indicate a significant interaction. They also indicate a significant effect due to the method and to the teacher. However, since the interaction was significant, this would be the primary concern of any further analysis. This significant interaction was not explored further in the study since the researcher's main concern lay in the analysis of covariance rather than the analysis of variance. The latter is shown for comparative purposes.

Analysis of Variance--Application Gain Scores

The summary of the within-cell information required for the analysis of the Application Gain Scores is shown in Table 20.

TABLE 20

THE NUMBER OF OBSERVATIONS, THE SUM OF THE APPLICATION GAIN SCORES, THE SUM OF THE APPLICATION GAIN SCORES SQUARED FOR EACH SUBGROUP

		Conventional Group	Introductory Group	Review Group	Total
Teacher A	n_{ij}	52	21	52	125
	ΣX	613	172	666	1,451
	ΣX^2	8,199	1,868	10,058	20,125
Teacher B	n_{ij}	28	42	17	87
	ΣX	365	405	179	949
	ΣX^2	5,677	5,243	2,455	13,375
Teacher C	n_{ij}	27	52	45	124
	ΣX	229	677	523	1,429
	ΣX^2	2,911	10,511	7,257	20,679
Teacher D	n_{ij}	40	51	21	112
	ΣX	392	563	265	1,220
	ΣX^2	4,542	7,907	3,853	16,302
Teacher E	n_{ij}	29	20	50	99
	ΣX	366	190	583	1,139
	ΣX^2	5,292	2,062	7,845	15,199
Total	n_{ij}	176	186	185	547
	ΣX	1,965	2,007	2,216	6,188
	ΣX^2	26,621	27,591	31,468	85,680

n_{ij} = number of observations
ΣX = sum of the Application Gain Scores
ΣX^2 = sum of the Application Gain Scores squared

As in the case of the Recall Gain Scores, since the number of observations in each cell varied, the analysis of variance was based on the unweighted means. The data in the cells of Table 21 are the means of the respective n_{ij} observations in the cells. The totals represent the sums of the rows or columns of the subgroup means.

TABLE 21

CELL MEANS OF THE APPLICATION GAIN SCORES

	Conventional Group	Introductory Group	Review Group	Total
Teacher A	11.79	8.19	12.81	32.79
Teacher B	13.04	9.64	10.53	33.21
Teacher C	8.48	13.02	11.62	33.12
Teacher D	9.80	11.04	12.62	33.46
Teacher E	12.62	9.50	11.66	33.78
Total	55.73	51.39	59.24	166.36

Using the computational symbols of Part 2, Table 18, and the computational formulas of Part 3, Table 18, the variance of the Application Gain Scores was analyzed. The results appear in Table 22.

TABLE 22

ANALYSIS OF VARIANCE OF THE APPLICATION GAIN SCORES

Source of variation	SS	df	MS	F
A (teacher)	5.95	4	1.49	0.05
B (method)	193.69	2	96.84	3.55 **
AB (interaction)	1,026.94	8	128.37	4.71 **
Within cell	14,509.45	532	27.27	

* Significant at the .05 level of confidence
** Significant at the .01 level of confidence

The analysis of variance of the Application Gain Scores shows a significant interaction. It also indicates that the treatment (method) effect was significant, but the teacher effect was not.

Analysis of Variance--Total Gain Scores

The summary of the within-cell information required for the analysis of the Total Gain Scores is shown in Table 23. Immediately following is Table 24 which gives the means of the respective n_{ij} observations of each cell.

TABLE 23

THE NUMBER OF OBSERVATIONS, THE SUM OF THE TOTAL GAIN SCORES, THE SUM OF THE TOTAL GAIN SCORES SQUARED FOR EACH SUBGROUP

		Conventional Group	Introductory Group	Review Group	Total
Teacher A	n_{ij}	52	21	52	125
	ΣX	1,126	348	1,226	2,700
	ΣX^2	27,166	7,354	33,740	68,260
Teacher B	n_{ij}	28	42	17	87
	ΣX	647	772	353	1,772
	ΣX^2	17,771	17,862	8,859	44,492
Teacher C	n_{ij}	27	52	45	124
	ΣX	452	1,368	1,047	2,867
	ΣX^2	10,196	40,958	28,421	79,575
Teacher D	n_{ij}	40	51	21	112
	ΣX	606	1,046	470	2,122
	ΣX^2	10,768	26,816	12,180	49,764
Teacher E	n_{ij}	29	20	50	99
	ΣX	784	434	1,240	2,458
	ΣX^2	22,944	10,374	33,638	66,956
Total	n_{ij}	176	186	185	547
	ΣX	3,615	3,968	4,336	11,919
	ΣX^2	88,845	103,364	116,838	309,047

TABLE 24

CELL MEANS OF THE TOTAL GAIN SCORES

	Conventional Group	Introductory Group	Review Group	Total
Teacher A	21.65	16.57	23.58	61.80
Teacher B	23.11	18.38	20.76	62.25
Teacher C	16.74	26.31	23.27	66.32
Teacher D	15.15	20.51	22.38	58.04
Teacher E	27.03	21.70	24.80	73.53
	103.68	103.47	114.79	321.94

Using the computational symbols of Part 2, Table 18, and the computational formulas of Part 3, Table 18, the variance of the Total Gain Scores was analyzed. The results appear in Table 25.

TABLE 25

ANALYSIS OF VARIANCE OF THE TOTAL GAIN SCORES

Source of variation	SS	df	MS	F
A (teacher)	1,448.96	4	362.24	4.480 *
B (method)	524.43	2	262.22	3.243 *
AB (interaction)	3,470.38	8	433.80	5.365 **
Within cell	43,016	532	80.86	

* Significant at the .05 level of confidence
** Significant at the .01 level of confidence

The analysis of variance of the Total Gain Scores indicates that there was a significant interaction, significant at the .01 level of confidence. The variation due to teacher and to method of instruction was significant at the .05 level of confidence.

Analysis of Covariance

In the analysis of covariance, the residual variation about an over-all regression line is partitioned. The over-all regression line is fitted to the entire set of data disregarding the treatment classes. All of the individual student gain scores could be adjusted using the multiple regression equations cited previously. The difference between these "predicted gain scores" and the actual gain scores is referred to as the residual. The residual variation is partitioned in the analysis of covariance just as the total criterion variation is partitioned in the analysis of variance.

The procedure of finding each student's predicted gain score and subtracting it from his actual gain score could be quite tedious in view of the number of students involved. Therefore, the computational formulas set forth by B. J. Winer were used.[1] These formulas appear in Table 26.

TABLE 26

COMPUTATIONAL FORMULAS FOR THE ANALYSIS OF COVARIANCE

	$(1x) = \bar{n}_h\bar{G}^2{}_x/pq$	$(1y) = \bar{n}_h\bar{G}^2{}_y/pq$	$(1z) = \bar{n}_h\bar{G}^2{}_z/pq$
	$(2x) = \Sigma X^2$	$(2y) = \Sigma Y^2$	$(2z) = \Sigma Z^2$
	$(3x) = \bar{n}_h q(\Sigma\bar{A}^2{}_x)$	$(3y) = \bar{n}_h q(\Sigma\bar{A}^2{}_y)$	$(3z) = \bar{n}_h q(\Sigma\bar{A}^2{}_z)$
	$(4x) = \bar{n}_h p(\Sigma\bar{B}^2{}_x)$	$(4y) = \bar{n}_h p(\Sigma\bar{B}^2{}_y)$	$(4z) = \bar{n}_h p(\Sigma\bar{B}^2{}_z)$
	$(5x) = \bar{n}_h(\Sigma\overline{AB}^2{}_x)$	$(5y) = \bar{n}_h(\Sigma\overline{AB}^2{}_y)$	$(5z) = \bar{n}_h(\Sigma\overline{AB}^2{}_z)$
(1)			
	$(1xy) = \bar{n}_h\bar{G}_x\bar{G}_y/pq$	$(1xz) = \bar{n}_h\bar{G}_x\bar{G}_z/pq$	$(1yz) = \bar{n}_h\bar{G}_y\bar{G}_z/pq$
	$(2xy) = \Sigma XY$	$(2xz) = \Sigma XZ$	$(2yz) = \Sigma YZ$
	$(3xy) = \bar{n}_h q(\Sigma\bar{A}_x\bar{A}_y)$	$(3xz) = \bar{n}_h q(\Sigma\bar{A}_x\bar{A}_z)$	$(3yz) = \bar{n}_h q(\Sigma\bar{A}_y\bar{A}_z)$
	$(4xy) = \bar{n}_h p(\Sigma\bar{B}_x\bar{B}_y)$	$(4xz) = \bar{n}_h p(\Sigma\bar{B}_x\bar{B}_z)$	$(4yz) = \bar{n}_h p(\Sigma\bar{B}_y\bar{B}_z)$
	$(5xy) = \bar{n}_h(\Sigma\overline{AB}_x\overline{AB}_y)$	$(5xz) = \bar{n}_h(\Sigma\overline{AB}_x\overline{AB}_z)$	$(5yz) = \bar{n}_h(\Sigma\overline{AB}_y\overline{AB}_z)$
	$A_{xx} = (3x) - (1x)$	$A_{yy} = (3y) - (1y)$	$A_{zz} = (3z) - (1z)$
	$B_{xx} = (4x) - (1x)$	$B_{yy} = (4y) - (1y)$	$B_{zz} = (4z) - (1z)$
	$AB_{xx} = (5x) - (3x) - (4x) + (1x)$	$AB_{yy} = (5y) - (3y) - (4y) + (1y)$	$AB_{zz} = (5z) - (3z) - (4z) + (1z)$
	$S_{xx} = (2x) - G^2{}_x/N$	$S_{yy} = (2y) - G^2{}_y/N$	$S_{zz} = (2z) - G^2{}_z/N$
	$E_{xx} = \Sigma(n_{ij}s^2{}_{ijx})$	$E_{yy} = \Sigma(n_{ij}s^2{}_{ijy})$	$E_{zz} = \Sigma(n_{ij}s^2{}_{ijz})$
(2)			
	$A_{xy} = (3xy) - (1xy)$	$A_{xz} = (3xz) - (1xz)$	$A_{yz} = (3yz) - (1yz)$
	$B_{xy} = (4xy) - (1xy)$	$B_{xz} = (4xz) - (1xz)$	$B_{yz} = (4yz) - (1yz)$
	$AB_{xy} = (5xy) - (3xy) - (4xy) + (1xy)$	$AB_{xz} = (5xz) - (3xz) - (4xz) + (1xz)$	$AB_{yz} = (5yz) - (3zy) - (4yz) + (1yz)$
	$S_{xy} = \Sigma XY - (\Sigma X\Sigma Y)/N$	$S_{xz} = \Sigma XZ - (\Sigma X\Sigma Z)/N$	$S_{yz} = \Sigma YZ - (\Sigma Y\Sigma Z)/N$
	$E_{xy} = \Sigma(XY_{ij} - \Sigma X_{ij}\Sigma Y_{ij}/n_{ij})$	$E_{xz} = \Sigma(XZ_{ij} - \Sigma X_{ij}\Sigma Z_{ij}/n_{ij})$	
		$E_{yz} = \Sigma(YZ_{ij} - \Sigma Y_{ij}\Sigma Z_{ij}/n_{ij})$	

---

[1] B. J. Winer, Statistical Principles in Experimental Design, pp. 599 - 605.

TABLE 26--Continued

Pooled within-class regression coefficients:

$$b_{y \cdot x} = \frac{E_{zz}E_{xy} - E_{xz}E_{yz}}{E_{xx}E_{zz} - E^2_{xx}} \qquad b_{y \cdot z} = \frac{E_{xx}E_{yz} - E_{xx}E_{xy}}{E_{xx}E_{zz} - E^2_{xx}}$$

Total group regression coefficients:

$$b_{y \cdot xT} = \frac{S_{zz}S_{xy} - S_{xz}S_{yz}}{S_{xx}S_{zz} - S^2_{xx}} \qquad b_{y \cdot zT} = \frac{S_{xx}S_{yz} - S_{xx}S_{xy}}{S_{xx}S_{zz} - S^2_{xx}}$$

Treatment regression coefficients:

$$b_{y \cdot xB} = \frac{(B + E)_{zz}(B + E)_{xy} - (B + E)_{xz}(B + E)_{yz}}{(B + E)_{xx}(B + E)_{zz} - (B + E)^2_{xx}}$$

$$b_{y \cdot zB} = \frac{(B + E)_{xx}(B + E)_{yz} - (B + E)_{xz}(B + E)_{xy}}{(B + E)_{xx}(B + E)_{zz} - (B + E)^2_{xx}}$$

(3)

Level regression coefficients:

Replace (B + E) by (A + E) in above coefficients.

Interaction regression coefficients:

Replace (B + E) by (AB + E) in Treatment Regression Coefficients

Adjusted within sum of the squares

$$E'_{yy} = E_{yy} - b_{y \cdot x} E_{xy} - b_{y \cdot z}E_{yz}$$

Adjusted sum of the squares for treatments:

$$B'_{yy} = (B + E)_{yy} - b_{y \cdot xB}(B + E)_{xy} - b_{y \cdot zB}(B + E)_{yz} - E'_{yy}$$

(4) Adjusted sum of the squares for levels:

Replace (B + E) by (A + E) in the equation for the sum of the squares for treatments

Adjusted sum of the squares for interaction:

Replace (B + E) by (AB + E) in the equation for the sum of the squares for treatments

The symbol $\overline{n}_h$ was discussed on page 60. Other symbols that appear in Table 26 and clarification of these symbols follows:

1. $\overline{G}$ = the sum of the subgroup means.
2. p = the number of levels, 5.
3. q = the number of treatments, 3.
4. $\overline{A}$ = the mean of the subgroup means of a given level.
5. $\overline{B}$ = the mean of the subgroup means of a given treatment.
6. $\overline{AB}$ = a subgroup mean.
7. G = the sum of the score.
8. N = the total number of observations, 547.

Analysis of Covariance--Recall Gain Scores

A summary table of the data needed for the analysis of covariance of the Recall Gain Scores was constructed using Table 26, Parts 1 and 2, as the guide. This summary data appears in Table 27. The x refers to the ITED Composite Score, the y to the Recall Gain Score, and the z to the Recall Pre-Test Score.

Part 2 of Table 27 indicates the sources of the variation, A representing the levels or teachers; B, the treatments or methods; AB, the interaction between teacher and method; E, the error or within-cell; and S, the total variation.

In actuality, each cell has its own regression coefficients based on the data within the cell. If the regression coefficients within each of the cells are homogeneous, then within-cell information from all of the cells may be pooled to provide a single estimate of the regression coefficients. To determine if the regression coefficients within each of the cells were homogeneous, the pooled within-class regression coefficients were found using the formulas found in Table 26, Part 3.

TABLE 27

SUMMARY DATA FOR THE RECALL GAIN SCORES

(1)	(1x) =	102,988.37	(1y) =	50,568.34	(1z) =	32,801.51
	(2x) =	138,029.00	(2y) =	74,993.00	(2z) =	44,790.00
	(3x) =	103,040.93	(3y) =	50,739.81	(3z) =	32,801.82
	(4x) =	104,208.33	(4y) =	51,900.00	(4z) =	32,921.03
	(5x) =	105,632.92	(5y) =	52,895.62	(5z) =	33,177.60
	(1xy) =	72,165.89	(1xz) =	58,122.13	(1yz) =	40,727.33
	(2xy) =	94,127.00	(2xz) =	75,286.00	(2yz) =	49,926.00
	(3xy) =	72,260.38	(3xz) =	58,124.01	(3yz) =	40,728.89
	(4xy) =	72,883.97	(4xz) =	58,481.96	(4yz) =	40,958.87
	(5xy) =	73,822.95	(5xz) =	58,992.28	(5yz) =	41,203.55
(2)	A_{xx} =	1,223.43	A_{yy} =	1,359.19	A_{zz} =	124.91
	B_{xx} =	52.16	B_{yy} =	180.72	B_{zz} =	0.09
	AB_{xx} =	1,375.90	AB_{yy} =	822.02	AB_{zz} =	255.07
	E_{xx} =	12,043.93	E_{yy} =	12,117.32	E_{zz} =	4,671.61
	S_{xx} =	14,894.00	S_{yy} =	14,948.47	S_{zz} =	5,022.37
	A_{xy} =	718.40	A_{xz} =	360.14	A_{yz} =	231.23
	B_{xy} =	94.81	B_{xz} =	1.56	B_{yz} =	2.19
	AB_{xy} =	843.86	AB_{xz} =	508.45	AB_{yz} =	242.80
	E_{xy} =	6,190.85	E_{xz} =	4,423.99	E_{yz} =	447.87
	S_{xy} =	8,141.05	S_{xz} =	5,302.95	S_{yz} =	1,060.58

The regression coefficients within each cell were also found using the same formulas, but utilizing only the data within each cell.

The sum of the squares of the residuals about the regression plane based on the pooled within-cell regression coefficients is given by the formula,

$$E'_{yy} = E_{yy} - b_{y.x}E_{xy} - b_{y.z}E_{yz}$$

The sum of the squares of the residuals based on the within-cell regression coefficients (not pooled) was determined using the formula,

$$E'_{yy} = E_{yy} - \Sigma(b_{y.x}E_{xy} - b_{y.z}E_{yz})$$

in which the data within the parentheses varied from cell to cell.

The error variation based on the pooled within-cell regression coefficients was 7,841.51; the error variation based on the unpooled within-cell regression coefficients was 7,377.68. The difference between these two variations, 463.83, is the variation of the within-cell regression coefficients about the pooled within-cell regression coefficients. The larger this value or source of variation, the less reasonable it is to assume that the within-cell regression coefficients are equal or homogeneous. A test of the hypothesis that the within-cell regression coefficients are homogeneous was made using the formula,

$$F = \frac{S_2/(2k - 2)}{S_1/(N - 3k)}$$

in which S_2 is the difference between the error variations determined by the two procedures described, S_1 is the error variation based on the unpooled within-cell regression coefficients, N is the total number of observations, and k is the number of cells.

TABLE 28

HOMOGENEITY OF WITHIN-CELL REGRESSION FOR THE RECALL GAIN SCORES

Source of variation	SS	df	MS	F
S_2	463.83	28	16.57	1.13
S_1	7,377.68	502	14.70	
Total	7,841.51	530		

Table 28 indicates that the F ratio was not significant and, therefore, the hypothesis of homogeneous within-cell regression coefficients was retained.

Utilizing the formulas found in Table 26, an analysis of covariance of the Recall Gain Scores was made. The analysis is summarized in Table 29. The experimental data indicates statistically significant differences between the teacher groups even after an adjustment was made for the effect of the covariates. There was no significant interaction and the differences between the treatment or method groups were not significant. The analysis of variance of the Recall Gain Scores (Table 19) showed a significant interaction and a significant difference between the treatment groups and between the teacher groups. However, when an adjustment was made for the covariates, the first two significant effects disappeared. This would indicate that these two significant differences were due to the effect of the covariates. When the latter effect is removed, the only significant difference remaining was that between the teacher groups. Regardless of which method of instruction was used, one teacher was more effective than another.

TABLE 29

ANALYSIS OF COVARIANCE OF THE RECALL GAIN SCORES

Source of variation	SS	df	MS	F
A (teacher)	991.92	4	247.98	16.76 **
B (method)	79.68	2	39.84	2.69
AB (Interaction)	165.85	8	20.73	1.40
Within cell	7,841.51	530	14.80	

** Significant at the .01 level of confidence

The adjusted Recall Gain Scores have the form,

$$\overline{Y}'_i = \overline{Y}_i - b_{y.x}(\overline{X}_i - \overline{X}) - b_{y.z}(\overline{Z}_i - \overline{Z})$$

in which $\overline{Y}'_i$ = the adjusted mean for a teacher group

$\overline{Y}_i$ = the unadjusted mean for a teacher group

$b_{y.x}$ and $b_{y.z}$ = the pooled within-cell regression coefficients

X and Z = the covariates

Table 30 shows the means for the five teacher groups on the unadjusted Recall Gain Score, the ITED Composite Score, the Recall Pre-Test Score, and the adjusted Recall Gain Score.

TABLE 30

THE ADJUSTED AND UNADJUSTED RECALL GAIN SCORE MEANS, THE ITED COMPOSITE SCORE MEANS, AND THE RECALL PRE-TEST SCORE MEANS FOR THE TEACHER GROUPS

	Unadjusted Recall Gain	Composite	Recall Pre-Test	Adjusted Recall Gain
Teacher A	9.67	13.27	8.11	10.65
Teacher B	9.64	13.10	7.56	10.42
Teacher C	11.06	14.43	8.36	11.35
Teacher D	8.19	15.84	8.54	7.55
Teacher E	13.25	17.36	9.13	11.86
	$b_{y \cdot x} = .73$	$b_{y \cdot z} = -.60$		

In comparing two adjusted means, the actual number of observations upon which the mean is based may be used. To determine which of the differences between the Adjusted Recall Gain Score means were significant, a "t" test was applied using the formula,

$$t = \frac{\bar{Y}'_1 - \bar{Y}'_2}{MS'_W \left(\frac{1}{n_1} + \frac{1}{n_2}\right)}$$

in which $\bar{Y}'_1 - \bar{Y}'_2$ = the difference between two adjusted Recall Gain Score means

MS'_W = the adjusted within-cell mean square, 14.80

n_1 and n_2 = the number of observations in the respective teacher groups

A "t" of 1.99 is significant at the .05 level of confidence and a "t" of 2.63 is significant at the .01 level. At the .01 level of confidence, the Adjusted Recall Gain Score mean of Teacher D was significantly lower than the Adjusted Recall Gain Score means of the other four teachers. At the .05 level of confidence, the Adjusted Recall Gain Score means of Teachers C and E were significantly higher than those of Teachers B and D and that of Teacher E was significantly higher than the adjusted mean of Teacher A. The Adjusted Recall Gain Score means of Teachers A and B were significantly higher than that of Teacher D. There were no significant differences between the Adjusted Recall Gain Score means of Teachers C and E, or between Teachers A and B and C.

Analysis of Covariance--Application Gain Scores

The same procedure as discussed in the previous section was followed in the analysis of covariance of the Application Gain Scores. The summary data appears in Table 31.

TABLE 31

SUMMARY DATA FOR THE APPLICATION GAIN SCORES

(1)	(1x) = 102,988.37	(1y) = 57,731.30	(1z) = 19,008.99
	(2x) = 138,029.00	(2y) = 85,680.00	(2z) = 28,780.00
	(3x) = 103,040.93	(3y) = 57,737.25	(3z) = 19,425.15
	(4x) = 104,208.33	(4y) = 57,924.99	(4z) = 19,026.20
	(5x) = 105,632.92	(5y) = 58,923.45	(5z) = 19,718.33
	(1xy) = 77,109.38	(1xz) = 44,246.56	(1yz) = 33,127.04
	(2xy) = 100,993.00	(2xz) = 58,620.00	(2yz) = 40,191.00
	(3xy) = 77,175.40	(3xz) = 44,860.94	(3yz) = 33,165.33
	(4xy) = 77,248.93	(4xz) = 44,262.68	(4yz) = 33,113.70
	(5xy) = 78,251.46	(5xz) = 45,417.91	(5yz) = 33,435.36
(2)	A_{xx} = 1,223.43	A_{yy} = 5.95	A_{zz} = 416.16
	B_{xx} = 52.16	B_{yy} = 193.69	B_{zz} = 17.21
	AB_{xx} = 1,375.90	AB_{yy} = 992.52	AB_{zz} = 275.98
	E_{xx} = 12,043.93	E_{yy} = 14,508.95	E_{zz} = 5,235.67
	S_{xx} = 14,894.00	S_{yy} = 15,677.54	S_{zz} = 6,051.16
	A_{xy} = 66.02	A_{xz} = 614.38	A_{yz} = 38.29
	B_{xy} = 139.55	B_{xz} = 16.12	B_{yz} = -13.34
	AB_{xy} = 936.51	AB_{xz} = 540.85	AB_{yz} = 283.37
	E_{xy} = 7,039.91	E_{xz} = 4,359.95	E_{yz} = 172.21
	S_{xy} = 8,150.38	S_{xz} = 5,717.11	S_{yz} = 302.72

In Table 31, the x refers to the ITED Composite Score, the y to the Application Gain Score, and the z to the Application Pre-Test Score.

The analysis of the homogeneity of within-cell regression, shown in Table 32, indicates that the hypothesis of homogeneous within-cell regression coefficients can be retained. As was stated before, retention of this hypothesis is important in the analysis of covariance.

TABLE 32

HOMOGENEITY OF WITHIN-CELL REGRESSION FOR THE APPLICATION GAIN SCORES

Source of variation	SS	df	MS	F
S_2	634.37	28	22.66	1.38
S_1	8,213.79	502	16.36	
Total	8,848.16	530		

The analysis of covariance of the Application Gain Scores, shown in Table 33, resulted in a statistically significant difference between teacher groups after adjustment was made for the covariates. There was no significant interaction and the differences between treatment or method groups were not significant.

TABLE 33

ANALYSIS OF COVARIANCE OF THE APPLICATION GAIN SCORES

Source of variation	SS	df	MS	F
A (teacher)	260.93	4	65.23	3.91 **
B (method)	0.38	2	0.19	0.01
AB (interaction)	253.80	8	31.72	1.90
Within cell	8,848.16	530	16.69	

** Significant at the .01 level of confidence

Table 34 shows the means for the five teacher groups on the unadjusted Application Gain Score, the ITED Composite Score, the Application Pre-Test Score, and the adjusted Application Gain Score.

TABLE 34

THE ADJUSTED AND UNADJUSTED APPLICATION GAIN SCORE MEANS, THE ITED COMPOSITE SCORE MEANS, AND THE APPLICATION PRE-TEST SCORE MEANS FOR THE TEACHER GROUPS

	Unadjusted Application Gain	Composite	Application Pre-Test	Adjusted Application Gain
Teacher A	10.93	13.27	5.78	11.80
Teacher B	11.07	13.10	5.46	11.88
Teacher C	11.04	14.43	6.19	11.23
Teacher D	11.15	15.84	6.23	10.21
Teacher E	11.26	17.36	8.16	10.33

$b_{y.x} = .82$ $\qquad$ $b_{y.z} = -.65$

In applying the "t" test to the differences between the adjusted Application Gain Score means of the teacher groups, it was found that the adjusted mean of Teacher D was significantly lower than the means of the other four teachers. The difference was significant at the .01 level of confidence. There were no other significant differences at this level of confidence.

At the .05 level of confidence, the adjusted mean of Teacher D was significantly lower than that of the other four teachers. The adjusted means of Teachers A, B, and C were significantly higher than that of Teacher E.

The Analysis of Covariance--Total Gain Scores

The Recall Gain Score and the Application Gain Score within each cell were adjusted using the appropriate pooled within-cell regression coefficients. The sum of these two adjusted scores became the Adjusted Total Gain Score for the cell. An analysis of variance of these adjusted scores was performed. An analysis of covariance is, in actuality, an analysis of variance of adjusted scores. The analysis of covariance of the Total Gain Scores, shown in Table 35, resulted in a statistically significant difference between teacher groups after the adjustment was made for the covariates. There was no significant interaction and the difference between treatment or method groups was not significant.

TABLE 35

ANALYSIS OF COVARIANCE OF THE TOTAL GAIN SCORES

Source of variation	SS	df	MS	F
A (teacher)	1473.76	4	368.44	8.02 **
B (method)	204.32	2	102.16	2.22
AB (interaction)	49.13	8	6.14	0.13
Within cell	24,340.74	530	45.93	

** Significant at the .01 level of confidence

The Adjusted Total Gain Scores for the teacher groups were:

1. Teacher C.....22.58
2. Teacher A.....22.45
3. Teacher B.....22.30
4. Teacher E.....22.19
5. Teacher D.....17.76

Application of the "t" test showed that the Adjusted Total Gain Score for Teacher D was significantly lower than the Adjusted Total Gain Scores of the other four teachers. The significance was at the .01 level. There were no other significant differences.

Student Reaction to Programed Material

At the conclusion of the unit of instruction, students in the Introductory and Review Groups were given a short questionnaire to complete. The purpose of the questionnaire was to determine whether (1) student attitude toward the programed material had changed as the unit progressed, (2) the student felt that use of the programed material had helped him to learn more than he would have by reading the textbook, and (3) the student would like to use programed material again.

The replies to the first part of the questionnaire are summarized for the two groups in Table 36.

TABLE 36

CHANGE IN STUDENT ATTITUDE TOWARD PROGRAMED MATERIAL

Question	Introductory Group	Review Group	Total
1. I liked using the programed material at the beginning of the unit and I continued to like it at the end.	42 22.7%	46 25.0%	88 23.8%
2. I liked using the programed material at the beginning of the unit, but it became boring and tiresome toward the end.	77 41.6%	60 32.6%	137 37.1%
3. I did not like using the programed material at the beginning of the unit and I did not like it at the end.	11 5.9%	10 5.4%	21 5.7%
4. I did not like using the programed material at the beginning of the unit, but I found it more interesting and fun toward the end.	10 5.4%	19 10.3%	29 7.9%
5. I cannot say that I liked using the programed material or that I disliked using it. I just used it.	39 21.1%	46 25.0%	85 23.0%

As an approximation, out of every twenty students, (1) five liked using the programed material throughout the unit of instruction,

(2) eight became bored with the material, (3) one did not like using it at all, (4) one found it more fun toward the end of the unit, and (5) five were neutral. A greater percentage of students in the Introductory Group became bored with the programed material than was true of the Review Group. However, the difference was not significant. A greater percentage of the Review Group became more interested in the programed material as the unit progressed than was true of the Introductory Group. Again, the difference in percentages was not significant.

Combining the responses to Questions 1 and 2 and combining the responses to Questions 3 and 4, one finds that

1. 64.3 percent of the Introductory Group and 57.6 percent of the Review Group liked using the programed material at the beginning of the unit.

2. 11.4 percent of the Introductory Group and 15.8 percent of the Review Group did not like using the programed material at the beginning of the unit.

3. 24.3 percent of the Introductory Group and 26.6 percent of the Review Group were neutral or expressed no opinion as to their feelings toward the programed material at the beginning of the unit.

Combining the responses to Questions 1 and 3 and combining the responses to Questions 2 and 4, one finds that

1. 28.1 percent of the Introductory Group and 35.3 percent of the Review Group liked using the programed material at the conclusion of the unit.

2. 47.6 percent of the Introductory Group and 38.0 percent of the Review Group did not like using the programed material at the conclusion of the unit.

Thus, about one-half of the Introductory Group was bored with or disliked using the programed material at the conclusion of the unit, while one-fourth of the group liked using the material. On the other hand, the students in the Review Group were about equally divided in their feeling toward the programed material at the conclusion of the unit. About one-third of the Review Group liked it, one-third disliked it, and one-third had no opinion.

Table 37 shows the results on the second part of the student questionnaire.

TABLE 37

STUDENT COMPARISON OF PROGRAMED LEARNING TO TEXTBOOK LEARNING

Question	Introductory Group	Review Group	Total
1. I feel that using programed material helped me to learn more than I would just reading the textbook.	113 61.1%	136 73.9%	249 67.5%
2. I do not feel that using programed material helps me to learn as much as I would learn from reading the textbook.	26 14.1%	19 10.3%	45 12.2%
3. I feel that I learn as much, but no more, by using programed material as I do by reading the textbook.	40 21.6%	27 14.7%	67 18.2%

As Table 37 indicates, about seven students out of every ten expressed the opinion that the use of the programed material helped them to learn more than they would have learned using the textbook alone. Approximately one student out of every ten felt that the programed material did not help him.

The percentage of the Review Group expressing a favorable opinion of the value of the programed material was considerably greater than was true of the Introductory Group. The difference in percentages of the two groups on Question 1, Table 37, was significant at the .01 level of confidence.

On the third part of the questionnaire, students were asked to express their desire or lack of desire to use programed material again. As was true of the first two parts of the questionnaire, the Review Group expressed a more favorable attitude toward programed material than did the Introductory Group.

1. 41.6 percent of the Introductory Group and 51.1 percent of the Review Group said, "I would like to use programed material again."

2. 22.2 percent of the Introductory Group and 17.4 percent of the Review Group said, "I would not like to use programed material again."

3. 34.1 percent of the Introductory Group and 29.9 percent of the Review Group said, "I do not care one way or the other whether I use programed material again."

In summary, the reaction of the "typical" student involved in this study was that though he did find the programed material somewhat boring toward the end of the unit, he did feel that the material helped him to learn more than he would have by use of only the textbook. In addition, he would like to use programed material again.

Teacher Data

Five Physical Science instructors were involved in this study. As one might expect, their experience and training varied. Table 38 tabulates the information collected relating to the teachers.

TABLE 38

EXPERIENCE AND TRAINING OF THE TEACHERS TAKING PART IN THE STUDY

	Teacher				
	A	B	C	D	E
1. Years of teaching experience	5	8	23	41	4
2. Years teaching in Grand Forks	5	4	19	36	3
3. Years teaching 9th grade science	5	7	12	30	3
4. Semester hours in chemistry	14	8	40	12	12
5. Semester hours in physics	18	19	15	10	16
6. Undergraduate major in physical science	No	No	Yes	No	No
7. Undergraduate minor in physical science	No	No	No	No	No

Correlations between the gain scores and the data of Table 38 were determined using the Rank Difference Formula,

$$r = 1 - \frac{6\ (\Sigma D^2)}{N(N^2 - 1)}$$

in which D = the difference in ranks, and
N = the number of observations, 5.

Correlations between the Adjusted Gain Scores (Recall, Application, and Total) and years of teaching experience were negative, but they were not statistically significant. Correlations between the Adjusted Gain Scores and years of teaching in Grand Forks were also negative but not significant. Correlations between the Adjusted Gain Scores and years teaching 9th grade science were negative but not significant. Correlations between the Adjusted Recall Gain Score and the semester hours of chemistry was positive but not significant. The same was true of the correlation between the Adjusted Total Gain Score and semester hours of chemistry. The correlation between the Adjusted Application Gain Score and hours of chemistry was negative but not significant. The correlations between the Adjusted Gain Scores and the semester hours of physics were positive and, in the case of the correlation between the Adjusted Application Gain Score and semester hours of physics, statistically significant at the .05 level of confidence. Finally, the correlation between the teachers' grading practices and the Adjusted Application Gain Score was a -1.00, which was significant. The most lenient grader among the teachers had the lowest Adjusted Application Gain Score, whereas the least lenient grader had the highest score.

Perhaps the best that can be said is that there appeared to be no correlation between teacher success, as determined by the Adjusted Gain Scores, and teacher experience or training.

Teacher A was the only teacher to express a preference for the use of programed material as review assignments. The other four teachers preferred using programed material as initiatory assignments. They were unanimous in their opinion that the use of programed material as initiatory assignments improved the quality of the class discussion and recitation that followed. This was in comparison to the use of textbook reading assignments as initiatory activity for the Conventional Group. They were also unanimous in their opinion that the use of the programed material had resulted in an increased interest and greater success in the course for a number of the students. There appeared to be some "carry-over" value for a number of students. This was particularly true for the so-called "average" student.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The Problem

The purpose of this study was to determine which of three methods of Physical Science instruction was the most effective for five Physical Science instructors in the Grand Forks Public Schools. The three methods were (1) conventional instruction, (2) a combination of conventional instruction and programed instruction in which the latter was used as initiatory assignments, and (3) a combination of conventional instruction and programed instruction in which the latter was used as review assignments. The study was also designed to determine whether the methods of instruction varied in effectiveness regardless of the teacher and whether the teachers varied in effectiveness regardless of the method.

In addition, the study was made to determine whether there was a significant correlation between student achievement, as measured by the three gain scores, and (1) student intelligence, as measured by the California Test of Mental Maturity, (2) student achievement in mathematics and the reading of science, as measured by the Iowa Test of Educational Development, and (3) the student's general achievement level, as measured by the Iowa Test of Educational Development.

Method

Twenty-three sections of ninth-grade Physical Science students were randomly assigned to one of the three treatment groups. The only restriction placed upon the assignment of these sections was that each of the five teachers should have at least one section, but no more than two sections, in each of the treatment groups.

A criterion test, prepared by the researcher, was administered to all students as the pre-test. The criterion test was divided into two parts, a Recall Test and an Application Test.

The programed material, also prepared by the researcher, was divided into 12 parts. Students in the Introductory Group used each part of the program as an initiatory assignment followed by any methodology of the teacher's choosing. Students in the Review Group used the programed material as review assignments. Students in the Conventional Group did not use the programed material.

The time spent on the unit of instruction varied from teacher to teacher with a minimum of 22 class periods and a maximum of 30 class periods. However, due to extenuating circumstances, time was not considered as a factor.

At the conclusion of the unit, the criterion test was administered as the post-test. In addition, students in the Introductory and Review Groups were asked to complete a short questionnaire designed to determine their reaction toward the programed material.

The Kuder-Richardson formula #20 was used to estimate the reliability of the Recall Test, the Application Test, and the Total Test. The three test scores were also correlated to course grades as a measure of their validity.

Background information on each student was gathered by the researcher after the unit of instruction was begun. This information included the Quantitative Score, the Science Reading Score, and the Composite Score on the Iowa Test of Educational Development. The Intelligence Quotient, as measured by the California Test of Mental Maturity, was also obtained.

Following the completion of the unit, correlations between the predictor variables and the three gain scores were determined. Multiple regression coefficients were found for the Recall Gain Score and the Application Gain Score. An analysis of variance and an analysis of covariance were made of the Recall Gain Scores, the Application Gain Scores, and the Total Gain Scores. Student response to a questionnaire was also analyzed and correlations between the Adjusted Gain Scores and teacher experience and training were computed.

Findings and Conclusions

The null hypothesis of no significant difference in the effectiveness of the three instructional methods, as measured by the Adjusted Recall Gain Score, the Adjusted Application Gain Score, and the Adjusted Total Gain Score, was retained. The analysis of covariance for each of these Gain Scores showed that after the adjustment for the covariates had been made, the three instructional methods did not differ significantly. The Adjusted Recall Gain Score for the Review Group was the highest, while that for the Conventional Group was the lowest. The Adjusted Application Gain Score for the Review Group was the highest, while that for the Introductory Group was the lowest. Finally, the Adjusted Total Gain Score for the Review Group was the highest, while that for the Introductory Group was the lowest. However, the differences were not statistically significant.

The null hypothesis of no significant difference in the effectiveness of the five teachers, as measured by Adjusted Recall Gain Score, the

Adjusted Application Gain Score, or the Adjusted Total Gain Score, was rejected. The analysis of covariance of each of these gain scores showed that after the adjustment for the covariates had been made, the five teachers did differ significantly. The Adjusted Recall Gain Score was the highest for Teacher E, the Adjusted Application Gain Score was the highest for Teacher B, and the Adjusted Total Gain Score was the highest for Teacher C.

The null hypothesis of no significant interaction of the teacher with the instructional method, as measured by the Adjusted Recall Gain Score, the Adjusted Application Gain Score, or the Adjusted Total Gain Score, was retained. The analysis of covariance of the three adjusted gain scores showed that no interaction was present. In all cases, the teachers were the most effective with the Review Group.

The hypothesis of no significant correlation between intelligence and achievement, as measured by the three gain scores, was rejected. In each of the three treatment groups, the correlation between intelligence and the gain scores was positive and significant. The correlation was the highest for the Introductory Group and lowest for the Conventional Group. As a predictor variable, intelligence ranked fourth for the Recall Gain Score, third for the Application Gain Score, and fourth for the Total Gain Score.

The hypothesis of no significant correlation between ability to read materials in natural science and achievement, as measured by the three gain scores, was rejected. In each of the treatment groups, the correlation between the gain scores and the ITED Science Reading Scores was positive and significant. The correlation was highest for the Introductory Group and lowest for the Review Group. As a predictor variable, the ITED Science Reading Score ranked third for the Recall Gain Score, fourth for the Application Gain Score, and third for the Total Gain Score.

The hypothesis of no significant correlation between mathematical ability and achievement, as measured by the three gain scores, was rejected. In each of the treatment groups, the correlation between the gain scores and the ITED Quantitative Scores was positive and significant. The correlation was the highest for the Introductory Group and lowest for the Review Group. As a predictor variable, the ITED Quantitative Score ranked second for each of the gain scores.

The hypothesis of no significant correlation between general achievement level and achievement, as measured by the three gain scores, was rejected. In each of the three treatment groups, the correlation between the gain scores and the ITED Composite Scores was positive and significant. The correlation was highest for the Introductory Group and lowest for the Review Group. As a predictor variable, the ITED Composite Score ranked first for each of the gain scores.

Student reaction to the programed material was varied. Generally, the Review Group was more favorable in its attitude toward programed material than was the Introductory Group. It was found that (1) 23.8 percent of the students liked using the programed material, (2) 37.1 percent liked using it at first, but found it became boring toward the end, (3) 5.7 percent of the students did not like using the material, (4) 7.9 percent did not like using the material at first, but thought it was more fun and interesting toward the end, and (5) 23.0 percent of the students had no feelings toward the programed material.

It was also found that 67.5 percent of the students felt that use of the programed material helped them to learn more than they would by use of the textbook alone, while 12.2 percent felt that use of only the textbook was preferable. Finally, 46.3 percent of the students would like to use programed material again, 19.8 percent would not like to use it, and 32.0 percent did not care one way or the other.

There was no significant correlation between the experience and training of the teachers and their effectiveness, as determined by the adjusted gain scores. The only exception was the correlation between the Adjusted Application Gain Scores and the semester hours of physics. It was significant at the .05 level of confidence.

Correlations between teaching experience and the adjusted gain scores tended to be negative but not significant.

The conclusions drawn from this study must be restricted to the ninth-grade students and to the five physical science instructors of the Grand Forks Public School System. In addition, they must be restricted to the unit, "Matter, Atoms, and Molecules," of the Physical Science course. Keeping these restrictions in mind, the following conclusions can be made:

1. The effectiveness of instruction is more dependent upon the teacher than upon a particular methodology.

2. Teachers vary in their effectiveness in teaching for the recall of facts and for the application of these facts.

3. Although a combination of conventional and programed instruction was not more effective than conventional instruction alone, students felt that they learned more when the two types of instruction were combined.

4. The best single predictor of student achievement is the general achievement level of the student.

5. Students like using programed material, but greater variety in the format of the material is necessary to maintain student interest over long periods of use.

6. Teacher effectiveness is not dependent upon total teaching experience, experience in the system, and experience teaching a given course.

7. Teacher effectiveness does appear to be related to college training in the area of instruction.

8. Lack of experience in the preparation of programed material is not a deterrent to the production and effective use of such material.

9. Teachers prefer to use programed material as initiatory assignments rather than as review assignments.

10. The quality of the classroom discussion and recitation is improved by the use of programed material and there appears to be a "carry-over" effect into succeeding non-programed units for many of the students.

11. Students prefer to use programed material as review assignments. The feeling of achievement or success with programed material appears to be enhanced if the student has had contact with the subject matter prior to using the programed material.

12. The more favorable a student's attitude is toward programed material, the greater will be his achievement.

Recommendations

From the review of the data presented in this study and the foregoing conclusions, the following recommendations are made:

1. The Physical Science instructors of the Grand Forks Public

School System should give consideration to the preparation of programed materials to be used in the Physical Science course. These materials should be varied in their format and they should be varied in step-size. A large-step program may prove more challenging to the better students.

2. The instructors should give consideration to the preparation of programed materials to be used in teaching only those parts of a unit that cannot be effectively taught by presently available techniques, or aids. The researcher is of the opinion that the programing of an entire unit may be wasteful of the teacher's time. He agrees with Pressey in that, generally, textbooks are excellently written and have but a few weak areas of coverage. These weak areas need elaboration and clarification and it is here that programed materials may be effectively used.

3. In future experimental studies, the instructors should give consideration to the use of student recorders to maintain a log of class activities. Comparisons of methodologies is more meaningful if accurate logs are maintained.

4. A further examination of the data of this study should be made to determine if there is a significant correlation between student achievement and the social-economic background of the student.

5. A further examination of the data of this study should be made to determine if there are any significant differences in the achievement of girls as compared to boys and whether the significance of the predictor variables differs for the two sexes.

APPENDIX A

THE CRITERION TEST

Student's Name______________________________ Section Number__________

School__________________________

MATTER, ATOMS, and MOLECULES

Part 1 DIRECTIONS: Write on the line at the right of each statement the number preceding the word or expression that best completes the statement.

1. Matter which has a definite volume and a definite shape is in the (1)gaseous state; (2)liquid state; (3)solid state; (4)vapor state. ____ 1
2. Which of the following is an example of a physical change? (1)The burning of wood; (2)The decaying of a plant; (3)The evaporation of gasoline; (4)The souring of milk. ____ 2
3. Which of the following is an example of a chemical change? (1)The dissolving of sugar in coffee; (2)The grinding of a piece of chalk into fine powder; (3)The melting of ice; (4)The rusting of iron. ____ 3
4. The following are qualities or characteristics of a substance. Which one is a physical property? (1)It burns; (2)It freezes; (3)It unites with oxygen at high temperature; (4)It will tarnish in the presence of sulfur. ____ 4
5. Of the following characteristics of a substance, which one is a chemical property? (1)It dissolves in water; (2)It is very hard; (3)It reacts with acid to form a new substance; (4)Its color is red. ____ 5
6. The symbol for chlorine is (1)C; (2)Ch; (3)Cl; (4)Cn. ____ 6
7. The substance that cannot be further decomposed by chemical means is (1)iron sulfide; (2)silver; (3)sugar; (4)water. ____ 7
8. The symbol Δ is used in a chemical equation to stand for (1)electricity; (2)heat; (3)pressure; (4)solubility. ____ 8
9. The electron of an atom (1)is electrically neutral; (2)is negatively charged; (3)is positively charged; (4)weighs more than a proton. ____ 9
10. The atomic number of an element is represented by the number of (1)electrons in the K shell; (2)electrons in the L shell; (3)neutrons in the nucleus; (4)protons in the nucleus. ____10
11. Subtracting the atomic number of an atom from its atomic weight gives the number of (1)electrons; (2)neutrons; (3)protons; (4)shells. ____11
12. The particle that occupies the first shell of the hydrogen atom is the (1)electron; (2)neutron; (3)nucleus; (4)proton. ____12
13. For a particular element, atoms have a(n) (1)equal number of electrons and neutrons; (2)equal number of protons and electrons; (3)equal number of protons and neutrons; (4)positive charge. ____13
14. Molecules move most rapidly in (1)crystals; (2)gases; (3)liquids; (4)solids. ____14
15. According to the Kinetic Theory, an increase in the temperature of a gas causes the molecules to (1)diffuse at a slower rate; (2)move faster; (3)move more slowly; (4)stop. ____15

Part 2 DIRECTIONS: Write the correct answers in the spaces provided.

16. When a substance passes directly from the solid state to the gaseous state, we call this process ________________.

17. The breaking up of a compound by means of an electric current is called ________________.

18. The solubility of a gas in a liquid increases if you lower the temperature or increase the ________________.

19. A solution that contains only a small amount of solute is said to be ________________.

20. The smallest particle of an element that can combine chemically with other elements is called a(n) ________________.

21. Matter cannot be created or destroyed by ordinary chemical means. This statement is known as the Law of ____________________.

22. When tiny visible particles of one liquid are scattered throughout another, the result is a(n) ________________.

23. Protons and neutrons weigh about ________ times as much as electrons.

24. The chemical formula for water is ________.

25. The first scientific atomic theory was proposed in 1803 by ____________.

26. The maximum number of electrons that can be present in the K shell of an atom is ________.

27. The number of electrons that an atom of an element will give up or accept during a chemical reaction is called its ________________.

28. A group of atoms that acts like a single atom in a chemical reaction is called a(n) ________________.

29. The mixing of substances because of molecular motion is called ________________.

30. The qualities or characteristics by which you can identify a substance are called its ________________.

Part 3 DIRECTIONS: Write on the line at the right of each statement the number preceding the word or expression that best completes the statement.

31. Suppose a quart of gasoline is vaporized. The vapor is then burned to form carbon dioxide and water. Which of the following is true? (1)Both a physical and a chemical change have occurred; (2)Matter has been destroyed; (3)Only a chemical change has occurred; (4)Only a physical change has occurred. ____31

32. The number of elements present in sugar ($C_{12}H_{22}O_{11}$) is (1)1; (2)2; (3)3; (4)45. ____32

33. A crystal of salt is added to a salt water solution. No change occurs in the crystal. The original solution is (1)dilute; (2)saturated; (3)supersaturated; (4)unsaturated. ____33

34. A true solution is always (1)colorless; (2)odorless; (3)saturated; (4)uniform. ____34

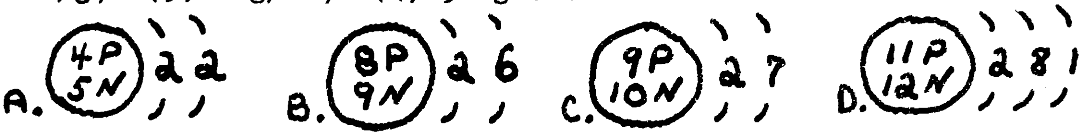
5. A substance that is made up of more than one kind of atom (1)cannot be a compound; (2)cannot be a crystal; (3)may be a mixture; (4)must be an element. ____35

36. A compound has the formula, XY_3. If X has a valence number of +3, Y has a valence number of (1) -9; (2) -3; (3) -1; (4) +1. ____36

37. In the equation, Fe + xHCl $\rightarrow$ $FeCl_2$ + H_2, the number representing x is (1)1; (2)2; (3)3; (4)4. ____37

38. A chemist found that substance A would dissolve in water faster if the water was cooled. The best guess is that substance A is (1)a gas; (2)a liquid; (3)a solid; (4)water. ____38

39. A 10 g. marble has a volume of 5 cc. Its density is (1)2; (2) 2 cc/g; (3) 2 g/cc; (4) 50 g-cc. ____39



40. The atom above that has an atomic weight of 9 is (1)A; (2)B; (3)C; (4)D. ____40

41. The atom above that has a valence number of -1 is (1)A; (2)B; (3)C; (4)D. ____41

42. The element above that has an atomic number of 9 is (1)A; (?)B; (3)C; (4)D. ____42

43. The atom above that will gain one electron in chemical reactions is (1)A; (2)B; (3)C; (4)D. ____43

44. The element above that can be found in Period 3 of the Periodic Table is (1)A; (2)B; (3)C; (4)D. ____44

45. The element above that can be found in Group VI [redacted] of the Periodic Table is (1)A; (2)B; (3)C; (4)D. ____45

<u>Part 4</u> DIRECTIONS: Write the correct answers in the spaces provided.

46. Complete the following chemical equation: 2 MgO $\rightarrow$ 2 Mg + ______.

47. How many atoms of sulfur are in sulfuric acid, H_2SO_4? ______

48. If 5 grams of substance X combine with 8 grams of substance Y to form 13 grams of XY, then 10 grams of substance X will combine with _____ grams of substance Y.

49. An atom of element X has one electron in its outer shell. Its valence number is _____.

50. What is the name of the compound whose formula is ZnO? ________________.

51. The valence number of silver is +1; the valence number of sulfur is -2. The chemical formula for silver sulfide is __________.

52. The valence number of calcium is +2; the valence number of the hydroxide radical is -1. The chemical formula for calcium hydroxide is __________.

An atom of a certain element has 17 electrons, 17 protons, and 18 neutrons.

53. The element's atomic number is __________.

54. The element's atomic weight is __________.

55. The number of electrons in the K shell of the atom is __________.

56. The number of electrons in the L shell of the atom is __________.

57. The number of electrons in the first energy level of the atom is __________.

58. The number of electrons in the third energy level of the atom is __________.

59. The number of electrons in the N shell of the atom is __________.

60. The element can be found in the Periodic Table in Period number __________.

APPENDIX B

DIRECTIONS TO THE TEACHERS

DIRECTIONS

Pre-Test

1. To be administered to all your sections.

2. Probably the students will not know the answers to the majority of the questions. They may guess, if they so desire.

3. Be sure that they enter their names, school, and section number.

4. Set a time limit. I would think that 30-35 minutes would be sufficient, but use your own judgment. If it is obvious that most of the class is finished in 20 minutes, close it off.

5. Collect the test and place in file folders in box. I will be by to pick the tests up.

6. Answer no questions about the test. Tell them they will learn the answers to their questions in the study of the unit.

7. I would appreciate it if, in case some students are absent the day the test is administered, that they make it up (given the same time limit as the others were given).

8. I would assume that the pre-test will be given at the start of a class period, but it does not have to be done this way.

Use of the Programed Material

I would suggest that following the test,

1. Sections using conventional instruction be started on the unit by any means you desire--perhaps a textbook assignment.

2. Sections using programed instruction, regardless of whether for introduction or for review, should be given Part 1 of the program and its answer sheet.

3. Point out that it is called a <u>program</u> and each numbered section is a <u>frame</u>. Later on in the program, I may refer them to a previous frame and I want them to know what I mean.

4. Hve them fold a sheet of paper to use as a mask. It should cover the width of the program paper.

5. They are to place the mask on the program with only Frame 1 exposed above the mask.

6. Read the first frame to them and have each write his answer on the answer sheet.

7. Sliding the mask down will expose the correct answer and also Frame 2.

8. Note the asterik by the answer blank in Frame 1. This indicates either a multiple-choice question or that some specific directions regarding the answer should be noted. Somewhere in the same frame you will find an asterik and the choices or directions. For example, in Frame 1, the asterik indicates that the student is to choose either Yes or No as his answer.

9. Certain words are underlined or capitalized for emphasis as in Frame 6. This might be pointed out, also.

10. Frame 7 calls for two answers, <u>a</u> and <u>b</u>. The correct answers are given as (a) liquids, (b) solids, followed by, "In any order." The two responses could have been reversed and still been correct.

11. Continue the oral treatment until you think they can continue the program on their own.

12. Part 1 should take about 25-30 minutes to complete. If the students have had that much time by the end of the class period, collect

their answer sheets and place in the filing box.

13. If the students should ask if it is permissible to look back at the frames they have already completed, the answer is yes. Actually, they could peek ahead at the correct answer and you probably would not be aware of it. Studies seem to indicate that cheating is not a factor to worry about when it comes to programed instruction. So don't worry.

14. Should a student answer a question wrong, have him check the incorrect answer and go on with the program. Point out that the answer sheets are not being graded. The only purpose in having him check an incorrect answer is to give me a chance to see where the program is weak. If a lot of students miss the same frame, I know that this particular frame will have to be rewritten.

The Introductory Group

1. If you keep in mind that before you begin a discussion of some particular subject matter, this group is to be introduced to the subject matter via programed material, you will encounter no difficulty.

2. Examples:

(a) There are 12 parts to the program. Since we have used Part 1 to introduce working with a program, let us consider only the last 11 parts. You could have them work for 30 minutes at the start of each period with a part of the program and then spend the remainder of the period in recitation, lecture, films, etc. This could be done for 11 days.

(b) Parts 4 and 5 deal with symbols. Perhaps you are not interested in discussing symbols for two half-days. You could give both parts to the students during the same class period. The next day you could discuss or quiz or develop in your own manner for half a period and then give the students Part 6 to complete in the remaining portion of the class period.

(c) You might give the students Part 7, for example, for the first 30 minutes of a class period. You then discuss, but feel that you would like to discuss again the following day. Do so. When you have completed the discussion to your satisfaction, start on Part 8.

(d) The students do <u>not</u> have to complete a part of the program at one sitting. You can given them 15 minutes at the close of a class period and 15 minutes at the beginning of the following class period. If there is an interruption in the completion of a part of the program, have the students slip their answer sheets into the program and collect.

<u>Review Group</u>

1. Keep in mind that these students are to use the programed material <u>after</u> you have completed your discussion and recitation.

2. Examples:

(a) You may spend half of each class period discussing the subject matter and half using the program to review what you have discussed (11 days).

(b) You may spend one, two, or three days discussing the subject matter of Parts 2 and 3 and then spend one day using the programed parts as a review.

(c) Do not save up all parts of the program for a lengthy review just before the post-test. This would require about 5 class periods of nothing but programed material. Space the review sessions.

(d) Suppose you discuss Part 7 in class for about 45 minutes. You then start the students on the review of Part 7. They will not be able to complete it by the end of the period. You can either have them complete it at the start of the next class period or as homework. If it is as homework, collect the answer sheets at the start of the next period.

(e) Collect the answer sheets from this group also. On the parts they were assigned to complete as homework, they may not complete these parts. Collect the answer sheets anyway.

The Log

I have tried to allow as much flexibility as possible in this study. I am asking that you keep a log of what you do in each class period. A notebook has been provided for this purpose. Examples of entries that might be made are:

1. Reading assignment--textbook, pages 10-12......20 minutes
   Recitation on the above assignment.............30 minutes

2. Recitation on pages 14-17 of textbook..........25 minutes
   Demonstration--"_____" ....10 minutes
   Written assignment, p. 22 of textbook..........15 minutes

3. Part 3 of program..............................30 minutes
   Recitation on above assignment.................20 minutes

4. Recitation on Part 6 of program................15 minutes
   Part 7 of program..............................25 minutes
   Demonstration--"_____" ....10 minutes

Absences

If a student misses any of the programed assignments, have him work on the assignments as homework or toward the end of a class period, if possible. If a student is a chronic absentee, make note of this for we may have to eliminate his test score from the study.

Textbook

You may use the textbook with your programed groups. If you want to assign textbook reading or questions at the end of the chapters, in addition to the programed material, you may do so. Simply enter this in the log.

Conclusion

I will be around checking periodically. Should a problem arise contact me by phone. There will be a short questionnaire for you and the students to complete at the end of the study.

Post-Test

I will deliver the post-test to you several days before you will need same. Be sure that the students fill in the blanks provided for their name, the name of the school, and their section number.

APPENDIX C

POST-TEST DATA

THE NUMBER OF CORRECT RESPONSES AND THE PERCENTAGE OF STUDENTS RESPONDING CORRECTLY TO EACH ITEM OF THE PRE- AND POST- RECALL TEST

	Pre-Test		Post-Test		Gain
Item	Number of Correct Responses	Percentage of Correct Responses	Number of Correct Responses	Percentage of Correct Responses	Number
1	506	92.5	533	97.4	27
2	98	17.9	268	49.0	170
3	300	54.8	410	75.0	110
4	121	22.1	304	55.6	183
5	386	70.6	434	79.3	48
6	392	71.7	526	96.2	134
7	126	23.0	297	54.3	171
8	176	32.2	458	83.7	282
9	238	43.5	400	73.1	162
10	258	47.2	451	82.4	193
11	143	26.1	391	71.5	248
12	183	33.5	453	82.8	270
13	183	33.5	373	68.2	190
14	343	62.7	404	73.9	61
15	378	69.1	438	80.1	60
16	3	0.5	252	46.1	249
17	3	0.5	177	32.4	174
18	127	23.2	300	54.8	173
19	20	3.7	222	40.6	202
20	168	30.7	376	68.7	208
21	5	0.9	218	39.9	213
22	2	0.4	80	14.6	78
23	0	0.0	253	46.3	253
24	380	69.5	524	95.8	144
25	0	0.0	360	65.8	360
26	47	8.6	493	90.1	446
27	4	0.7	310	56.7	306
28	7	1.3	217	39.7	210
29	1	0.2	121	22.1	120
30	62	11.3	372	68.0	310
Total	4,660	28.4	10,415	63.5	5,755

N = 547

THE NUMBER OF CORRECT RESPONSES AND THE PERCENTAGE OF STUDENTS RESPONDING CORRECTLY TO EACH ITEM OF THE PRE- AND POST- APPLICATION TEST

	Pre-Test		Post-Test		Gain
Item	Number of Correct Responses	Percentage of Correct Responses	Number of Correct Responses	Percentage of Correct Responses	Number
31	332	60.7	407	74.4	75
32	295	53.9	372	68.0	77
33	157	28.7	292	53.4	135
34	241	44.1	314	57.4	73
35	247	45.2	388	70.9	141
36	47	8.6	211	38.6	164
37	202	36.9	386	70.6	184
38	184	33.6	346	63.3	162
39	205	37.5	296	54.1	91
40	220	40.2	351	64.2	131
41	118	21.6	255	46.6	137
42	221	40.4	415	75.9	193
43	107	19.6	377	68.9	270
44	114	20.8	262	47.9	148
45	115	21.0	262	47.9	147
46	24	4.4	109	19.9	85
47	92	16.8	279	51.0	187
48	112	20.5	249	45.5	137
49	19	3.5	311	56.9	292
50	59	10.8	402	73.5	343
51	2	0.4	244	44.6	242
52	1	0.2	168	30.7	167
53	152	27.8	458	83.7	306
54	45	8.2	327	59.8	282
55	33	6.0	500	91.4	467
56	27	4.9	488	89.2	461
57	50	9.1	468	85.6	418
58	21	3.8	293	53.6	272
59	18	3.3	312	57.0	294
60	47	8.6	172	31.4	125
Total	3,507	21.4	9,714	59.2	6,207

THE NUMBER OF CORRECT RESPONSES AND THE PERCENTAGE OF STUDENTS RESPONDING CORRECTLY TO EACH ITEM OF THE POST-RECALL TEST FOR EACH OF THE TREATMENT GROUPS

	Conventional		Introductory		Review	
Item	Number of Correct Responses	Percentage of Correct Responses	Number of Correct Responses	Percentage of Correct Responses	Number of Correct Responses	Percentage of Correct Responses
1	171	97.2	182	97.8	180	97.3
2	78	44.3	88	47.3	102	55.1
3	125	71.0	138	74.2	147	79.5
4	87	49.4	114	61.3	103	55.7
5	128	72.7	149	80.1	157	84.9
6	171	97.2	178	95.7	177	95.7
7	83	47.2	104	55.9	110	59.5
8	139	79.0	165	88.7	154	83.2
9	125	71.0	132	71.0	143	77.3
10	138	78.4	149	80.1	164	88.6
11	121	68.7	128	68.8	142	76.8
12	148	84.1	152	81.8	153	82.7
13	109	61.9	138	74.2	126	68.1
14	128	72.7	136	73.1	140	75.7
15	133	75.6	150	80.7	155	83.8
16	70	39.8	88	47.3	94	50.8
17	54	30.7	60	32.3	63	34.1
18	98	55.7	93	50.0	109	58.9
19	58	33.0	77	41.4	87	47.0
20	109	61.9	135	72.6	132	71.4
21	48	27.3	91	48.9	79	42.7
22	24	13.6	18	9.7	38	20.5
23	78	44.3	84	45.1	91	49.2
24	168	95.4	179	96.2	177	95.7
25	93	52.9	125	67.2	142	76.8
26	150	85.2	170	91.4	173	93.5
27	84	47.7	104	55.9	122	66.0
28	70	39.8	71	38.2	76	41.1
29	40	22.7	33	17.7	48	25.9
30	100	56.8	129	69.3	143	77.3
Total	3,128	59.2	3,560	63.8	3,727	67.2
	N = 176		N = 186		N = 185	

THE NUMBER OF CORRECT RESPONSES AND THE PERCENTAGE OF STUDENTS RESPONDING CORRECTLY TO EACH ITEM OF THE POST-APPLICATION TEST FOR EACH OF THE TREATMENT GROUPS

	Conventional		Introductory		Review	
Item	Number of Correct Responses	Percentage of Correct Responses	Number of Correct Responses	Percentage of Correct Responses	Number of Correct Responses	Percentage of Correct Responses
31	116	65.9	143	76.9	148	80.0
32	117	66.4	116	62.4	139	75.2
33	76	43.2	96	51.6	120	64.9
34	104	59.1	104	55.9	106	57.3
35	131	74.4	131	70.4	126	68.1
36	76	43.2	62	33.4	73	39.5
37	131	74.4	129	69.3	126	68.1
38	102	57.9	126	67.7	118	63.8
39	91	51.8	91	48.9	114	61.7
40	114	64.8	106	57.0	131	70.9
41	88	50.0	85	45.6	82	44.3
42	131	74.4	139	74.7	145	78.4
43	123	69.9	126	67.7	128	69.2
44	73	41.5	99	53.2	90	48.7
45	68	38.7	93	50.0	101	54.6
46	38	21.6	38	20.4	33	17.9
47	82	46.6	84	45.1	113	61.1
48	77	43.8	82	44.0	90	48.7
49	101	57.4	107	57.5	103	55.7
50	120	68.1	150	80.6	132	71.4
51	81	46.0	77	41.4	86	46.5
52	61	34.6	59	31.8	48	25.9
53	145	82.4	158	85.0	155	83.8
54	119	67.6	101	54.3	107	57.8
55	156	88.7	171	91.9	173	93.5
56	155	88.1	164	88.2	169	91.4
57	145	82.4	156	83.9	167	90.3
58	87	49.4	89	47.8	117	63.3
59	96	54.6	94	50.5	122	66.0
60	38	21.6	78	41.9	56	30.3
Total	3,042	57.6	3,254	58.3	3,418	61.6

N = 176 N = 186 N = 185

APPENDIX D

THE PROGRAM

PART 1

	1.	Anything that occupies space and has weight is matter. A piece of wood occupies space and has weight; therefore, the piece of wood is matter. Is gasoline matter? *(___) *Yes or No
Yes	2.	Gasoline is matter because it occupies space and has (___).
weight	3.	Air is matter because it has weight and occupies (___).
space	4.	A cement block is matter because it occupies (a) and has (b).
a. space b. weight	5.	Matter is anything that has (a) and *(b). *two words
a. weight b. occupies space	6.	For convenience in studying the characteristics of substances, scientists have arranged them in three groups: solids, liquids, and gases. These three groups are called the STATES or PHASES OF MATTER. The three states of matter are solids, liquids, and (___).
gases	7.	The three phases of matter are gases, (a), and (b).
a. liquids b. solids (In any order)	8.	Wood and steel are examples of which of the three states or phases of matter? (___)
solid	9.	Water and gasoline are examples of the liquid phase or (___) of matter.
state	10.	Air is an example of the (___) state or phase of matter.
gas or gaseous	11.	Solids, liquids, and gases are called the three (a) or (b) of matter.
a. states b. phases (In any order)	12.	In the solid state, matter takes up a definite volume and has a definite shape. A steel ball has a definite shape; it is round. The steel ball also occupies a certain amount of space. Is the steel ball a solid? *(___) *Yes or No

Yes	13.	When we say a substance has a definite volume, we mean that it occupies a definite amount of space. We can measure the amount of space or volume that the substance occupies. A piece of wood is 3 feet long, 2 feet wide, and 1 foot thick. It occupies 6 cubic feet of space. In other words, its (___) is 6 cubic feet.
volume	14.	A piece of wood is a solid because it has a definite shape and a definite (___).
volume	15.	A marble is a solid. Therefore, we can be quite sure that the marble has a definite volume and a definite (___).
shape	16.	A solid is a substance that has a *(a) and a *(b). *two words
a. definite shape b. definite volume (In any order)	17.	The marble in No. 15 is a solid. It is also matter. It is matter because it *(a) and *(b).
a. occupies space b. has weight (In any order)	18.	Solids are one of the three states or (___) of matter.
phases	19.	The other two states or phases of matter are (a) and (b).
a. liquids b. gases (In any order)	20.	In the liquid state, matter has a definite volume but NO definite shape. Milk is a liquid because it has a definite (___).
volume	21.	Because it does not have a definite shape, milk cannot be a (___).
solid	22.	Another liquid is gasoline. Gasoline has a definite (a) but no definite (b).
a. volume b. shape	23.	Our most common liquid is water. Water has a *(a) but no *(b). *two words
a. definite volume b. definite shape	24.	A chair has a definite volume and a definite shape. Therefore, the chair is in the (___) state or phase.
solid	25.	Soda pop has a definite volume, but it takes the shape of the container it is in. Since different containers have different shapes, soda pop has no definite shape of its own. Thus, soda pop is in the (___) state or phase.

liquid	26.	Matter in the gaseous phase has no definite shape and no definite volume. Air is a gas because it has (_a_) definite shape and (_b_) definite volume.
a. no b. no	27.	Oxygen, at room temperature, has no definite shape and no definite volume. Therefore, oxygen is matter in the (___) state or phase.
gas or gaseous	28.	The oxygen in No. 27 cannot be a solid because it has no definite (_a_). It cannot be a liquid because it has no definite (_b_).
a. shape b. volume	29.	A gas completely fills its container. If the air in a balloon is released into this room, it would spread out until it (___) filled the room.
completely	30.	Oxygen has weight and occupies space. Therefore, oxygen is (___).
matter	31.	Which two phases of matter do not have definite shapes? (_a_) (_b_)
a. liquids b. gases (In any order)	32.	Some forms of matter can be changed from one state to another by changing the temperature. Ice can be changed into water by changing the (___).
temperature	33.	Water (a liquid) can be changed into ice (a solid) by (___) the temperature.
changing or lowering	34.	To change ice into water, you must *(___) the temperature. *raise or lower
raise	35.	To change water into ice, you must *(___) the temperature. *raise or lower
lower	36.	To change water (a liquid) into water vapor (a gas), you must *(___) the temperature. *raise or lower
raise	37.	When you melt a substance, you change that substance from the (_a_) state to the (_b_) state.
a. solid b. liquid	38.	To melt a substance, you must *(___) the substance until it reaches a temperature called the melting point. *heat or cool
heat	39.	When a liquid evaporates, it is changed from the (_a_) state or phase to the (_b_) phase.

a. liquid b. gas or gaseous	40.	To speed up the evaporation process, you would *(___) the liquid. *heat or cool
heat	41.	When a substance freezes, it is changed from the (a) state to the (b) state.
a. liquid b. solid	42.	To freeze a liquid you would *(___) it. *heat or cool
cool	43.	To change a gas to a liquid, you must *(___) the gas. *heat or cool
cool	44.	To change ice (a solid) into water vapor (a gas), you must heat the ice. The first thing that happens when you heat the ice is that it melts to form (___).
water or a liquid	45.	If you continue to heat the water that is formed, the water will boil to form (___).
water vapor or steam or a gas	46.	Most solids, like ice, when heated enough will change first into a (a) and then into a (b).
a. liquid b. gas	47.	Before most solids are changed into gases, they first are changed into (___).
liquids	48.	Some solids pass into the gaseous state without passing through the (___) state.
liquid	49.	The process in which a solid changes directly into a gas is called sublimation. At room temperature dry ice sublimes. In other words, it changes from a (a) directly into a (b).
a. solid b. gas	50.	A substance that changes from a solid directly to a gas undergoes the process called (___).
sublimation	51.	A substance that sublimes changes from the solid state in which it had a definite (a) and a definite (b) directly to a gas.
a. shape b. volume (In any order)	52.	In the gaseous state, the substance has (a) definite size and (b) definite shape. It completely (c) its container.
a. no b. no c. fills		

Student's Name____________________ School______________ Sec. No.________

PART 1

1. ____________________
2. ____________________
3. ____________________
4a. ____________________
4b. ____________________
5a. ____________________
5b. ____________________
6. ____________________
7a. ____________________
7b. ____________________
8. ____________________
9. ____________________
10. ____________________
11a. ____________________
11b. ____________________
12. ____________________
13. ____________________
14. ____________________
15. ____________________
16a. ____________________
16b. ____________________
17a. ____________________
17b. ____________________
18. ____________________
19a. ____________________
19b. ____________________
20. ____________________
21. ____________________
22a. ____________________
22b. ____________________
23a. ____________________
23b. ____________________
24. ____________________
25. ____________________
26a. ____________________
26b. ____________________
27. ____________________
28a. ____________________
28b. ____________________
29. ____________________
30. ____________________
31a. ____________________
31b. ____________________
32. ____________________
33. ____________________
34. ____________________
35. ____________________
36. ____________________
37a. ____________________
37b. ____________________
38. ____________________
39a. ____________________
39b. ____________________
40. ____________________
41a. ____________________
41b. ____________________
42. ____________________
43. ____________________
44. ____________________
45. ____________________
46a. ____________________
46b. ____________________
47. ____________________
48. ____________________
49a. ____________________
49b. ____________________
50. ____________________
51a. ____________________
51b. ____________________
52a. ____________________
52b. ____________________

PART 2

	1.	Any change in matter that does NOT produce a new substance is called a physical change. Breaking a piece of chalk into two pieces does not produce a new substance. Therefore, breaking the chalk is an example of a physical (___).
change	2.	Changing water into ice does not produce a new substance since ice is a form of water. Water is a liquid, while ice is in the (___) state or phase.
solid	3.	Because a new substance is not formed when water is changed to ice, you know that such a change is a (___) change.
physical	4.	When water evaporates, it changes from the liquid state to the (___) state.
gas or gaseous	5.	Water in the gaseous state or phase is called water vapor. Water and water vapor are made up of the same kinds of atoms. Water vapor is not a new substance. Thus, the change of water to water vapor is a *(___). *two words
physical change	6.	Water, ice, and water vapor are different states or phases of the same substance. They are all composed of two atoms of hydrogen and one atom of oxygen. The three states of matter are (a), (b), and (c).
a. solids b. liquids c. gases (In any order)	7.	When liquid (or melted) iron is cooled enough, it changes to solid iron. This change is an example of a *(___). *two words
physical change	8.	Liquid gasoline will evaporate. In doing so, it changes to the gaseous state. This is a physical change since no (___) substance is formed.
new	9.	Changing a substance from one state or phase to another is a *(___). *two words
physical change	10.	Any change in matter that does not produce a *(___) is a physical change. *two words

new substance	11.	Changes that produce new substances are called chemical changes. When milk sours, a new substance is formed. Therefore, the change that occurs when milk sours is a (___) change.
chemical	12.	When iron rusts, it is changed to iron oxide. Iron is made up of iron atoms; iron oxide is made up of iron atoms and oxygen atoms. Thus, when iron rusts, a new substance is formed. Such a change is a *(___). *two words
chemical change	13.	Food that is digested is changed to new substances. Digestion is an example of a (___) change.
chemical	14.	If you burn a strip of magnesium, it changes to a white powder. The white powder is called magnesium oxide. This is a chemical change since magnesium oxide is a *(___). *two words
new substance	15.	A chemical change is a change in matter that produces *(___). *two words
new substances	16.	The new substance(s) formed in a chemical change differ from the original substance(s) in chemical composition. You can be sure that sour milk differs from sweet milk in (___) composition.
chemical	17.	Iron oxide differs from iron in *(___). *two words
chemical composition	18.	Liquid oxygen and gaseous oxygen do not differ in chemical composition. Therefore, the change of gaseous oxygen to liquid oxygen is not a *(___). *two words
chemical change	19.	When we talk about the chemical composition of a substance, we are talking about the kinds of atoms and the number of atoms that make up that substance. If two substances differ in chemical composition, they are made up of different kinds of (_a_) or different numbers of (_b_).
a. atoms b. atoms	20.	Each substance has certain characteristics or qualities that help us identify it. These are called properties of the substance. A sweet taste is one of the (___) of sugar.

properties	21.	The white color of sugar is another one of its (___).
properties	22.	Properties that can be observed and measured are called PHYSICAL PROPERTIES. The color of a substance can be observed. It can also be measured by means of instruments, such as the spectroscope. Therefore, color is a (___) property.
physical	23.	You can observe that a block of wood has weight by noting that it sinks in water. You could, also, find the weight of the block by using a scale or balance. Since it can be observed and measured, weight is a *(___). *two words
physical property	24.	One can also measure the amount of sugar that will dissolve in a cup of coffee. One can observe it dissolve, also, since the sugar seems to disappear. The solubility of sugar in coffee or some other liquid is one of the properties of sugar. Solubility is a *(___). *two words
physical property	25.	A physical property is a characteristic of a substance that can be (_a_) and (_b_).
a. observed b. measured (In any order)	26.	Salt crystals have a characteristic shape that can be observed if you use a microscope. The shape can also be measured using special instruments. Since it can be observed and measured, the shape of salt crystals is a *(___). *two words
physical property	27.	The temperature at which water freezes or at which it boils can be observed and measured by using a thermometer. Freezing and boiling temperatures are examples of *(___). *two words
physical properties	28.	A physical property of a substance is a characteristic or property that *(___). *complete the sentence
can be observed and measured.	29.	Properties that tell about the reaction of a substance with other substances are called CHEMICAL PROPERTIES. The two types of properties are (_a_) and (_b_).

a. physical b. chemical (In any order)	30.	Iron, in the presence of moisture, will combine with oxygen to form iron oxide (rust). The rusting of iron is an example of a (___) property.
chemical	31.	The rusting of iron is also an example of a (___) change.
chemical	32.	Many substances will combine or react with oxygen in a process called burning. Therefore, one of the characteristics or properties of these substances is that they burn. Burning is a (___) property.
chemical	33.	When a substance burns, a new substance is formed. Burning is an example of a (___) change.
chemical	34.	Melting a solid changes it to a liquid. No new substance is formed. The melting of a solid is an example of a (___) change.
physical	35.	Since no new substance is formed when a solid melts, you can be sure that the solid has not combined or reacted with another substance. Melting is NOT a (___) property.
chemical	36.	Silverware will tarnish when it reacts with sulfur vapor. Silver sulfide, a new substance, is formed. This is a (___) change.
chemical	37.	A substance (such as silverware) that tarnishes reacts with another substance (such as sulfur vapor). Thus, when we say a substance will tarnish, we are describing one of its (___) properties.
chemical	38.	A chemical property is a characteristic of a substance that tells us how it (___) with other substances.
reacts	39.	The <u>density</u> of a substance is the weight or mass of a certain volume of that substance. Since weight and volume can be observed and measured, density is a *(___). *two words
physical property	40.	$\text{Density} = \frac{\text{Weight}}{\text{Volume}}$ To find the density of a block of iron, you would divide the weight of the block by its (___).

volume	41.	$\text{Density} = \frac{\text{Weight}}{\text{Volume}}$ A glass marble has a volume of 2 cubic centimeters. Before you could determine its density, you would also have to know the marble's (___).
weight	42.	$\text{Density} = \frac{\text{Weight}}{\text{Volume}}$ If a block of iron weighs 80 grams and its volume is 10 cubic centimeters, the density of the iron is (___) grams per cubic centimeter.
8	43.	A piece of wood is 2 feet long, 1 foot wide, and 1 foot thick. Volume = Length X Width X Thickness The volume of the piece of wood is (___) cubic feet.
2	44.	If the piece of wood above weighs 50 pounds, its density can be found as follows: $\text{Density} = \frac{\text{Weight}}{\text{Volume}} = \frac{\text{50 pounds}}{\text{2 cubic feet}} = \text{25 pounds per cubic foot}$ Suppose the piece of wood had weighed 20 pounds and its volume was 2 cubic feet. What would its density be? (___)
10 pounds/cubic foot	45.	Density equals (a) divided by (b).
a. weight b. volume	46.	Usually the density of a substance is expressed in pounds per cubic foot (lb/ft^3) in the English system, or in grams per cubic centimeter (g/cm^3) in the metric system. If a block of wood weighs 96 pounds and it has a volume of 4 cubic feet, its density equals 24 *(___). *Label the answer
pounds per cubic foot or lb/ft^3	47.	The density of a block of wood that weighs 100 grams and has a volume of 25 cubic centimeters is 4 *(___). *Label the answer
grams per cubic centimeter or g/cm^3	48.	A piece of copper weighs 900 grams. It is 10 centimeters long, 5 centimeters wide, and 2 centimeters thick. Its volume can be found as follows: Volume = Length X Width X Thickness The volume of the copper is (___).
100 cubic centimeters	49.	The density of the copper is *(___). *Do not forget to label the answer

9 g/cm^3	50.	A barrel contains 5 cubic feet of water. The water weighs 312 pounds. The density of the water is (a) pounds per (b).
a. 62.4 b. cubic foot	51.	$\text{Density} = \frac{(\ a\ )}{(\ b\ )}$
a. weight b. volume	52.	A sample of aluminum weighs 30 grams. Its density is 3 grams per cubic centimeter. $\text{Density} = \frac{\text{Weight}}{\text{Volume}}$ $3 \text{ grams/cm}^3 = \frac{30 \text{ grams}}{?? \text{ cm}^3}$ Dividing 30 by *(___) will give you the answer 3. *number
10	53.	Therefore, the volume of this aluminum sample is (___) cm^3.
10	54.	A lead block weighs 55 grams and its density is 11 grams/cm^3. Its volume is *(___). *Don't forget to label the answer
5 cm^3	55.	Suppose the lead block has a volume of 8 cm^3 and its density is 11 grams/cm^3. What is its weight? $\text{Density} = \frac{\text{Weight}}{\text{Volume}}$ $11 \text{ grams/cm}^3 = \frac{?? \text{ grams}}{8 \text{ cm}^3}$ Dividing *(___) by 8 gives the answer, 11. *number
88	56.	Therefore, the block must weigh *(___) grams. *number
88	57.	If a piece of copper weighs 450 grams and has a density of 9 g/cm^3, its volume is (___).
50 cm^3	58.	The weight and volume of this piece of copper can both be observed and measured. They are (___) properties.
physical		

Student's Name ______________________________ School ______________ Sec. No. ________

PART 2

1. ____________________

2. ____________________

3. ____________________

4. ____________________

5. ____________________

6a. ____________________

6b. ____________________

6c. ____________________

7. ____________________

8. ____________________

9. ____________________

10. ____________________

11. ____________________

12. ____________________

13. ____________________

14. ____________________

15. ____________________

16. ____________________

17. ____________________

18. ____________________

19a. ____________________

19b. ____________________

20. ____________________

21. ____________________

22. ____________________

23. ____________________

24. ____________________

25a. ____________________

25b. ____________________

26. ____________________

27. ____________________

28. ____________________

29a. ____________________

29b. ____________________

30. ____________________

31. ____________________

32. ____________________

33. ____________________

34. ____________________

35. ____________________

36. ____________________

37. ____________________

38. ____________________

39. ____________________

40. ____________________

41. ____________________

42. ____________________

43. ____________________

44. ____________________

45a. ____________________

45b. ____________________

46. ____________________

47. ____________________

48. ____________________

49. ____________________

50a. ____________________

50b. ____________________

51a. ____________________

51b. ____________________

52. ____________________

53. ____________________

54. ____________________

55. ____________________

56. ____________________

57. ____________________

58. ____________________

PART 3

1. A substance that cannot be broken up into simpler substances by ordinary chemical means is called an <u>element</u>.

Oxygen cannot be broken up into simpler substances by ordinary chemical means. This means that oxygen is a(n) (___).

element

2. By ordinary chemical means, we are referring to such things as heating, cooling, dissolving, and adding one substance to another.

Hydrogen is element. It cannot be broken up into *(___) by ordinary chemical means.

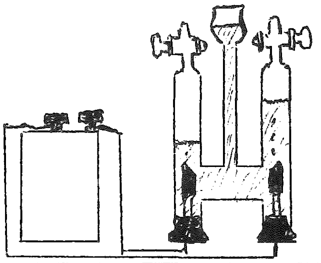
*two words

simpler substances

3. Iron is also an element. It cannot be broken up into *(a) by ordinary *(b). *two words

a. simpler substances
b. chemical means

4. Below is a diagram of an apparatus used to show that water is made up of two different gases.



The changing of water into two new substances, oxygen and hydrogen, is an example of a (___) change.

chemical

5. Since water can be broken up into two simpler substances simply by sending an electric current through it (an ordinary chemical means), you know that water is NOT a(n) (___).

element

6. When an electric current produces a chemical change in a liquid, the process is called <u>electrolysis</u>.

The apparatus pictured above may be used to demonstrate the process of (___).

electrolysis

7. Electrolysis is an example of a (___) change.

chemical

8. From the diagram above, you can observe that there is about twice as much *(a) gas in water as there is *(b) gas.

*hydrogen or oxygen

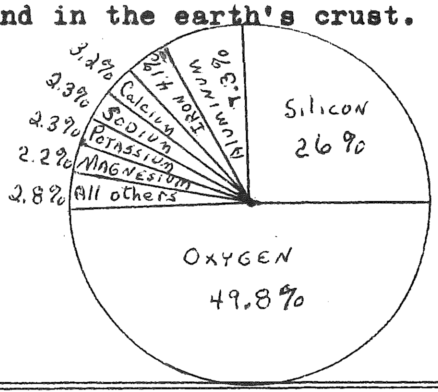
a. hydrogen
b. oxygen

9. Water can be broken up into oxygen and hydrogen by sending a(n) *(___) through it.

*two words

electric current

10. The process is called (___).

electrolysis	11.	Below is a circle graph which shows the relative abundance of the most common elements found in the earth's crust.  The most abundant element in the earth's crust is (___).
oxygen	12.	The second most abundant element in the earth's crust is (___).
silicon	13.	4.1% of the earth's crust is composed of (___).
iron	14.	Slightly over 75% of the earth's crust is composed of two elements. The two elements are (_a_) and (_b_).
a. oxygen b. silicon (In any order)	15.	About 97% of the earth's crust is composed of *(___) elements. *How many?
8	16.	Calcium is an element. Therefore, you know that it cannot be broken up into *(_a_) by *(_b_) means. *two words
a. simpler substances b. ordinary chemical	17.	A <u>compound</u> is a substance that is composed of two or more different elements that are united chemically. A compound <u>can</u> be broken be broken up into simpler substances by ordinary chemical means. Sugar is composed of the elements, carbon, hydrogen, and oxygen. These three elements are combined chemically. Therefore, sugar is a(n) (___).
compound	18.	Hydrogen and oxygen combine chemically to form water. Water is a(n) (___).
compound	19.	When a compound is broken up, it will form two or more simpler substances. Since these simpler substances differ from the compound, they are said to be new. The breaking up of a compound into two or more new substances is an example of a (___) change.
chemical	20.	When oxygen and hydrogen combine or unite, they form a different or new substance--water. The change that takes place is a (___) change.

chemical	21.	A compound differs from the elements of which it is made up in its characteristics or (___).
properties	22.	A compound is a substance that is composed of two or more different (a) that are united (b).
a. elements b. chemically	23.	Iron and sulfur combine chemically to form iron sulfide. Iron and sulfur are the (a) that unite (b) to form iron sulfide. Iron sulfide is a(n) (c).
a. elements b. chemically c. compound	24.	A mixture is a material containing two or more substances that have NOT united chemically. Each substance keeps its own characteristics or (___).
properties	25.	When sand is added to water, the two substances do not combine or react chemically. Therefore, sand in water is an example of a(n) (___).
mixture	26.	Neither the sand nor water lose their individual (___).
properties or characteristics	27.	The sand can be separated from the water by heating the mixture. Heating causes the water to evaporate and the sand is left behind in the container. When water evaporates, it is changed from the liquid state to the gaseous state. This is a (___) change.
physical	28.	A heterogeneous (het-er-o-jean-e-us) mixture is one in which the particles of the substances are not evenly distributed or spread out in each other. Most of the sand in the sand-water mixture will settle to the bottom of the container. The sand particles are NOT evenly distributed in the water. This is an example of a (___) mixture.
heterogeneous	29.	If you add a handful of black, powdered iron to a handful of yellow, powdered sulfur, the two elements do not combine chemically. Thus, they form a (___).
mixture	30.	Since the particles of iron and sulfur are not evenly spread out or distributed in each other, the mixture is said to be (___).
heterogeneous	31.	Neither the iron nor the sulfur lose their characteristic (___).
properties	32.	You could separate the iron particles from the sulfur particles by using a magnet. The magnet will attract the (___) particles.

iron	33.	When you put a sample of the iron-sulfur mixture in a test tube and heat it strongly, the iron unites chemically with the sulfur. A new substance, iron sulfide, is formed. The change that takes place in the iron-sulfur mixture is a (___) change.
chemical	34.	Iron sulfide differs from iron and from sulfur in its physical and chemical (___).
properties	35.	Because the iron and sulfur are chemically combined in iron sulfide, you know that iron sulfide is a(n) (___).
compound	36.	The smallest particle that exhibits all the properties of a compound is called a <u>molecule</u>. Suppose you took a lump of sugar and divided into two pieces and then took one of these pieces and divided it, in turn, into two pieces. If you continued this division, you would finally obtain the smallest particle that could be still identified as sugar. This particle would be one (___) of sugar.
molecule	37.	Each tiny grain of sugar is made up of many billions of sugar molecules. Thus, in size, the sugar molecule is very (___).
small	38.	The smallest particle that exhibits all the properties of a compound is called a (___).
molecule	39.	A compound is composed of two or more (___) that are united chemically.
elements	40.	Thus, a molecule must be made up of still smaller particles. These particles are called <u>atoms</u>. The smallest particle of an <u>element</u> that can combine chemically with other elements is a(n) (___).
atom	41.	A molecule is made up of (___) that are chemically united.
atoms	42.	Each molecule of a compound must have two or more different (___).
atoms	43.	One (a) of iron combines with one (b) of sulfur to form one (c) of iron sulfide.
a. atom b. atom c. molecule	44.	Molecules of some gases, for example oxygen and hydrogen, are made up of two identical atoms. Two atoms of oxygen combine to form one (___) of oxygen.

molecule

45. In a few cases, a molecule may consist of only one atom. A molecule of helium or argon, for example, contains only one atom.

Since a molecule of helium does not consist of two or more elements chemically combined, you know that helium is NOT a(n) (___).

compound

46. If several atoms of element A are put into a container with several atoms of element B and the atoms do not combine chemically, a (___) is formed.

mixture

47. If several atoms of element A are put into a container with several molecules of compound C and the atoms and molecules do not combine chemically, a (___) is formed.

mixture

48. If several molecules of compound C are put into a container with several molecules of compound D and the molecules do not combine chemically, a (___) is formed.

mixture

49. Thus, a mixture may be composed of elements (as in No. 46 above), or of a combination of an element with a compound (as in No. 47 above), or of (___)--as in No. 48 above.

compounds

50. A substance that cannot be broken up into simpler substances by ordinary chemical means is called a(n) (___).

element

51. The smallest particle of an element that can combine chemically with other elements is called a(n) (___).

atom

52. A substance composed of two or more different elements that are united chemically is called a(n) (___).

compound

53. The smallest particle that exhibits all the properties of a compound is called a(n) (___).

molecule

Student's Name________________ School__________ Sec. No.______

PART 3

1. __________
2. __________
3a. __________
3b. __________
4. __________
5. __________
6. __________
7. __________
8a. __________
8b. __________
9. __________
10. __________
11. __________
12. __________
13. __________
14a. __________
14b. __________
15. __________
16a. __________
16b. __________
17. __________
18. __________
19. __________
20. __________
21. __________
22a. __________
22b. __________
23a. __________
23b. __________
23c. __________
24. __________
25. __________
26. __________
27. __________
28. __________
29. __________
30. __________
31. __________
32. __________
33. __________
34. __________
35. __________
36. __________
37. __________
38. __________
39. __________
40. __________
41. __________
42. __________
43a. __________
43b. __________
43c. __________
44. __________
45. __________
46. __________
47. __________
48. __________
49. __________
50. __________
51. __________
52. __________
53. __________

PART 4

	1. Chemists use symbols as abbreviations for the different elements. To-date, 104 different (___) have been identified.
elements	2. For each element there is a different chemical (___).
symbol	3. You should be able to give the symbol for certain elements if you are given the name. You should also be able to name the element if you are given the symbol. The purpose of this particular part of the program is to help you learn the (a) and (b) of certain elements.
a. names b. symbols (In any order)	4. There are two major groups of chemical symbols. The first group uses one or two letters from the English name of the element. The second group uses one or two letters from the Latin name of the element. All chemical symbols contain *(a) or *(b) letters. *number
a. 1 b. 2	5. We will begin with the group of elements whose symbols are derived from their English names. Each symbol in this group contains *(a) or *(b) letters from the (c) name of the element.
a. 1 b. 2 c. English	6. If the symbol for an element is a single letter, that letter is always capitalized. The symbol for hydrogen is H. In the same manner, the symbol for oxygen is (___).
O	7. If the symbol of an element consists of two letters, the first letter is always capitalized; the second letter is always a small letter. The symbol for helium is He. The symbol for bromine consists of the first two letters of the word. The symbol for bromine is (___).
Br (Note; the second letter is a small letter.)	8. In writing the name of an element, the name is capitalized only if it is the first word in the sentence. A one-letter symbol is always capitalized. The first letter of a two-letter symbol is always capitalized. The symbol for hydrogen is (a). The symbol for helium is (b). The symbol, Br, represents (c).

a. H b. He c. bromine (Note: small "b" on bromine.)	9.	Helium and hydrogen are both very light gases. The symbols for these elements are (a) and (b).
a. He b. H (In any order)	10.	If the symbols of several elements begin with the same letter, the element which occurs most frequently, or is most useful, usually is assigned the single capital letter. H, *(a), occurs more frequently than He, *(b). *name
a. hydrogen b. helium	11.	Although both of these elements are very light gases, hydrogen, *(a), is very active and helium, *(b), is very inactive. *symbol
a. H b. He	12.	Another group of elements has symbols which begin with 'N'. The symbol for nitrogen is N. The symbol for nickel is Ni. The symbol for neon is Ne. The most common element in this group is nitrogen for its symbol is the single capital ( ).
N	13.	N or *(a) is a common inactive gas. Neon or **(b) is a rare stable gas. *name **symbol
a. nitrogen b. Ne	14.	Both of these elements *(a) and *(b) occur in the gaseous state at room temperature. *symbol
a. N b. Ne (In any order)	15.	N, *(a), forms some important compounds. Ne, *(b), forms no chemical compounds as yet. *name
a. nitrogen b. neon	16.	The third element whose symbol begins with N is nickel, Ni. N, (a), and Ne, (b), are gases, while nickel, *(c), is a solid metal. *symbol
a. nitrogen b. neon c. Ni	17.	Ni, *( ) is an important ingredient of special steels. *name
nickel	18.	Nitrogen and nickel begin with the same two letters. Nitrogen is more common so its symbol is (a), while the symbol for nickel is (b).

a. N b. Ni	19.	(a) is the symbol for nitrogen. (b) is the symbol for neon. (c) is the symbol for nickel.
a. N b. Ne c. Ni	20.	The chemical symbol of an element tells us what the element is and it also tells us that we are talking about one atom of that element. Ni, means that we are talking about the element (a), and that we are talking about *(b) atom of the element *number
a. nickel b. one	21.	The symbol H indicates that we are using *(a) atom(s) of the element (b). *number
a. one b. hydrogen	22.	The names of the elements magnesium and manganese begin with the same two letters. Their symbols are taken from the first and third letters of the English name. The symbol for magnesium is (a). The symbol for manganese is (b).
a. Mg b. Mn	23.	Mn, (a), and Mg, (b), are both metallic solids.
a. manganese b. magnesium	24.	Note that although the names of both elements begin with the same two letters, and although both names contain 'g' and 'n', the symbols consist of 'M' and the letter which occurs 3rd in the name. The symbol for manganese is (a). The symbol for magnesium is (b).
a. Mn b. Mg	25.	Light-weight ladders are frequently made of the metal, magnesium, *(___). *symbol
Mg	26.	*(___), manganese, is an important element in certain steels. *symbol
Mn	27.	Both Mg, (a), and Mn, (b), are mixed with other metals to form useful alloys.
a. magnesium b. manganese	28.	He, (a), and Ne, (b), are very stable gases.
a. helium b. neon	29.	Nickel, *(a), magnesium, *(b), and manganese, *(c), are metals. *symbols
a. Ni b. Mg c. Mn	30.	At room temperature H, (a), and N, (b), are both gases.

a. hydrogen b. nitrogen	31.	There are seven elements whose symbols begin with 'C'; we will study four of these at this time. The most common and the most important element of this group is carbon. Carbon is, therefore, assigned the capital letter (___).
C	32.	C, (___), is an element that occurs in all living things.
carbon	33.	Chemists have learned how to imitate and improve on nature and now produce many new compounds that also contain carbon, *(___). *symbol
C	34.	The formula for table sugar, $C_{12}H_{22}O_{11}$, indicates that this compound contains the three elements *(a), *(b), and *(c) in that order. *name
a. carbon b. hydrogen c. oxygen	35.	There is one important metal whose symbol consists of 'C' followed by the second letter of the name of the element. That metal is calcium. The symbol for calcium is (___).
Ca	36.	The element Ca, (___), occurs widely distributed over the earth in the rock called limestone.
calcium	37.	Limestone has the formula, $CaCO_3$. This formula shows that limestone contains the elements *(a), *(b), and *(c). *name
a. calcium b. carbon c. oxygen	38.	Manganese and magnesium derive their symbols from the first and third letters of their names since their names both begin with 'ma'. The symbol for manganese is (a). The symbol for magnesium is (b).
a. Mn b. Mg	39.	Both chromium and chlorine begin with the letters 'ch'. It is the third letter that is used in their symbols. Cl stands for (a). Cr stands for (b).
a. chlorine b. chromium	40.	The most common substance used in the United States for purifying water is Cl, (___).
chlorine	41.	Much of the bleaching in the United States is also done by chlorine, *(___). *symbol
Cl	42.	Cl, (a), is a gas and an active non-metal, while chromium, *(b), is an active solid metal. *symbol

a. chlorine
b. Cr

43. Stainless stell is composed of iron and about 18% of Cr, (___).

---

chromium

44. Two very stable gases are helium, (a), and neon, (b).
symbols

---

a. He
b. Ne

45. The metal Ni, (___), has magnetic properties.

---

nickel

46. Carbon, *(a), hydrogen, *(b), and nitrogen, *(c), occur in all proteins.
*symbol

---

a. C
b. H
c. N

47. Chromium, *(___), is a useful metal for protecting iron.
*symbol

Cr

48. Ca, (a), Mg, (b), and Mn, (c), never occur free in nature.

---

a. calcium
b. magnesium
c. manganese

49. Cl, (___), is a very active non-metal.

---

chlorine

50. Two important elements, whose names begin with 'A', take their symbols from their English names.

Aluminum is a light weight metal.
Argon is an inactive gas.

Many housewives wrap foods in Al, (___), foil.

---

aluminum

51. Argon, *(a), is one of the inactive gases like helium, *(b), and Ne, (c).
*symbol

---

a. Ar
b. He
c. neon

52. Aluminum, *(___), was once more expensive than gold.
*symbol

Al

53. Because it has almost no tendency to combine chemically, argon, *(___), is used to keep air from light bulbs.
*symbol

Ar

54. Sulfur has been used by mankind for thousands of years. Because it is so common, its symbol is the single letter (___).

S

55. S, (___), is often found in volcanic areas.

---

sulfur

56. Paper-making operations require great amounts of sulfur, *(___).
*symbol

S

57. Silicon, Si, has become much more important recently. Transistors require very pure silicon, *(___).
*symbol

Si	58. 'Bouncing putty' or 'nutty putty' is a complex compound containing Si, (___).
silicon	59. Ordinary sand is the most common compound of silicon, *(___). *symbol
Si	60. Silicon, *(a), and sulfur, *(b), have nonmetallic properties. *symbol
a. Si b. S	61. Five other nonmetallic elements have single letters for their symbols. These are boron, phosphorus, fluorine, iodine and oxygen. The symbol for iodine is (___).
I	62. Few people see I, (___), in its crystalline form.
iodine	63. Crystalline iodine, *(a), is a gray solid. An alcohol solution of I, (b), is used as an antiseptic. *symbol
a. I b. iodine	64. I, (a), and fluorine have many chemical properties in common. The symbol for fluorine is the single letter, (b).
a. iodine b. F	65. Note carefully the spelling of fluorine. The "u" comes before the "o". F, (a), is much more active than iodine, *(b). *symbol
a. fluorine b. I	66. In fact, fluorine, *(___), is the most active nonmetal. *symbol
F	67. The most abundant element by weight in the crust of the earth is oxygen. Its symbol is (___).
O	68. O, (___), is essential to living things.
oxygen	69. Oxygen, *(___), is a colorless gas at room temperature. *symbol
O	70. Although phosphorus is pronounced with the "f" sound, its symbol is the single letter 'P'. F is the symbol for (___).
fluorine	71. The symbol for phosphorus is its first letter, (___).
P	72. Because of its low kindling temperature, P, (___), is used in matches.
phosphorus	73. Boron is one of the lighter elements. Its symbol is (___).
B	

Student's name__________________________School________________Sec. No.________

PART 4

1. ____________________
2. ____________________
3a. ____________________
3b. ____________________
4a. ____________________
4b. ____________________
5a. ____________________
5b. ____________________
5c. ____________________
6. ____________________
7. ____________________
8a. ____________________
8b. ____________________
8c. ____________________
9a. ____________________
9b. ____________________
10a. ____________________
10b. ____________________
11a. ____________________
11b. ____________________
12. ____________________
13a. ____________________
13b. ____________________
14a. ____________________
14b. ____________________
15a. ____________________
15b. ____________________
16a. ____________________
16b. ____________________
16c. ____________________
17. ____________________
18a. ____________________
18b. ____________________
19a. ____________________
19b. ____________________
19c. ____________________
20a. ____________________
20b. ____________________
21a. ____________________
21b. ____________________
22a. ____________________
22b. ____________________
23a. ____________________
23b. ____________________
24a. ____________________
24b. ____________________
25. ____________________
26. ____________________
27a. ____________________
27b. ____________________
28a. ____________________
28b. ____________________
29a. ____________________
29b. ____________________
29c. ____________________
30a. ____________________
30b. ____________________
31. ____________________
32. ____________________
33. ____________________
34a. ____________________
34b. ____________________
34c. ____________________
35. ____________________
36. ____________________
37a. ____________________
37b. ____________________
37c. ____________________
38a. ____________________
38b. ____________________
39a. ____________________
39b. ____________________
40. ____________________
41. ____________________
42a. ____________________
42b. ____________________
43. ____________________
44a. ____________________
44b. ____________________
45. ____________________
46a. ____________________
46b. ____________________
46c. ____________________
47. ____________________
48a. ____________________
48b. ____________________
48c. ____________________
49. ____________________
50. ____________________
51a. ____________________
51b. ____________________
51c. ____________________
52. ____________________
53. ____________________
54. ____________________
55. ____________________
56. ____________________
57. ____________________
58. ____________________
59. ____________________
60a. ____________________
60b. ____________________
61. ____________________
62. ____________________
63a. ____________________
63b. ____________________
64a. ____________________
64b. ____________________
65a. ____________________
65b. ____________________
66. ____________________
67. ____________________
68. ____________________
69. ____________________
70. ____________________
71. ____________________
72. ____________________
73. ____________________

PART 5

	1. Boron has as its symbol the single letter "B". Three other important elements have symbols which also begin with "B". The first and second letters of their names provide the symbols for bromine, (_a_), bismuth, (_b_), and barium, (_c_).
a. Br b. Bi c. Ba	2. Br, *(___), is unusual in being an element which is a liquid at room temperature. *name
bromine	3. Many medicines contain compounds of bromine, (___). symbol
Br	4. Compounds of bismuth, Bi, are also used in medicine. Uncombined Bi, *(___), is a relatively low melting point metal. *name
bismuth	5. Bismuth, *(___), is used in alloys for type metal. *symbol
Bi	6. Barium has many chemical properties similar to Ca, (_a_). The symbol for barium is (_b_).
a. calcium b. Ba	7. Ba, (___), compounds are frequently used to make clear X rays of the digestive tract.
barium	8. Barium, *(___), does not occur free in nature. *symbol
Ba	9. Zinc is the metal used in galvanizing or plating steel. Its symbol is (___).
Zn	10. Note the spelling of z-i-n-c. It ends in c. Few words in English end in "nc." Today some automobiles are protected against corrosion by being undercoated with Zn, *(___). *name
zinc	11. The United States is the major world producer of zinc, *(___). *symbol
Zn	12. The chemical family called the halogens includes the elements fluorine, *(_a_), chlorine, *(_b_), bromine, *(_c_), and iodine, *(_d_). *symbol
a. F b. Cl c. Br d. I	13. The very stable gases include helium,*(_a_), and neon, *(_b_). *symbol

a. He b. Ne	14.	Light weight metals that are becoming very important in industry are aluminum, *(_a_), and magnesium, *(_b_). *symbol
a. Al b. Mg	15.	Water is a compound of the elements H, *(_a_), and O, *(_b_). *name
a. hydrogen b. oxygen	16.	Air is composed of about 80 per cent nitrogen, *(___). *symbol
N	17.	Gold and silver have been used for jewelry and coins since early times. The Latin word for gold is "aurum." Gold's chemical symbol comes from the first two letters of this word. The symbol for gold is (___).
Au	18.	Aureomycin, the antibiotic, gets its name from the same word. Aureomycin means "the golden mold." Au is the symbol for (___).
gold	19.	Becuase of its inactivity, gold, *(___), is used for jewelry and dental fillings. *symbol
Au	20.	Au is also used as a protective coating for other metals in the form of Au, *(___), plate. *name
gold	21.	Because it is so soft, gold, *(___), is frequently hardened by adding copper. *symbol
Au	22.	Silver gets its symbol from the first and third letters of the Latin word meaning silver, "argentum." The chemical symbol for silver is (___).
Ag	23.	Many other metals have the same color as Ag, *(___). *name
silver	24.	Electrum is the name given to a pale yellow alloy of silver, *(_a_), and gold, *(_b_). *symbol
a. Ag b. Au	25.	Knives, forks, and spoons may be made of almost pure Ag, *(_a_), or frequently they are Ag, *(_b_), plated. *name
a. silver b. silver	26.	United States currency is no longer based upon the gold, *(___), standard. *symbol
Au	27.	Among other metals, dental fillings may contain Au, *(_a_) or Ag, *(_b_). *name
a. gold b. silver	28.	Metal fillings for teeth also contain mercury. The Romans called silver "argentum," giving us the chemical symbol (___).

Ag	29.	They called the liquid metal we know as mercury, "hydrargyrum," (hydr = watery; argyrum = silver). Mercury, "hydrargyrum," has the chemical symbol, (___).
Hg	30.	Mercury is also known as quicksilver because it is a silvery liquid that is "quick" or lively. One of the few elements that is a liquid at ordinary room temperatures is Hg, *(___). *name
mercury	31.	Note the difference between Ag which is the symbol for (_a_) and mercury whose symbol is (_b_).
a. silver b. Hg	32.	Lead is less dense than Hg, *(___). *name
mercury	33.	An amalgam is a mixture of another metal and mercury, *(___). *symbol
Hg	34.	The major ore of mercury, *(___), is called cinnabar. *symbol
Hg	35.	Since it is a metal, Hg, *(___), will conduct electricity. *name
mercury	36.	The most accurate thermometers and barometers are filled with mercury, *(___). *symbol
Hg	37.	The Latin word for iron is ferrum. Its chemical symbol comes from the first two letters of this word. The symbol for iron is (___).
Fe	38.	The American economy is based to a great extent on Fe, *(___). *name
iron	39.	If air is perfectly dry, there is little tendency for iron, *(___), to rust. *symbol
Fe	40.	Steels are alloys of other metals with Fe, *(___). *name
iron	41.	The Mesabi range in Minnesota is a major source of iron, *(___), ore. *symbol
Fe	42.	The Latin word for copper is cuprum. Its symbol is Cu. Both brass and bronze are alloys of copper, *(___). *symbol
Cu	43.	All United States coins contain Cu, *(___). *name
copper	44.	Ag, *(_a_), is the best metallic conductor of electricity. Because it is so much cheaper however, the most commonly used conductor of electricity is Cu, **(_b_). *name **name

a. silver b. copper	45. Copper has the symbol (___).
Cu	46. Brass is an alloy of Cu, *(_a_), with Zn, *(_b_). *name
a. copper b. zinc	47. Bronze on the other hand is an alloy of copper, *(___), with tin. *symbol
Cu	48. The Latin word "stannum" provides the chemical symbol for tin. Tin is represented by (___).
Sn	49. It makes a sort of rhyme, "S-n" is tin. Tin is (___).
Sn	50. Bronze is so much more durable than brass that the Romans were interested in alloying copper, *(_a_), with tin, *(_b_), rather than with Zn, **(_c_). *symbol **name
a. Cu b. Sn c. zinc	51. The major reason that the Romans were interested in conquering Britain was that Cornwall had important mines of tin, *(___). *symbol
Sn	52. In modern days, Malaya is the major world producer of Sn, *(___). *name
tin	53. "Tin" cans consist of thin coating of tin, *(_a_), on a base of iron, *(_b_). *symbol
a. Sn b. Fe	54. The Romans were acquainted with the heavy, easily melted element we call lead and they called plumbum. The chemical symbol for lead is (___).
Pb	55. Roman water supplies and sewage disposal were excellent. A plumber originally worked with the metal *(_a_), **(_b_). *name **symbol
a. lead b. Pb	56. A heavy weight used to hold a string vertical is known as a plumb bob. It was often made of *(_a_), **(_b_). *name **symbol
a. lead b. Pb	57. Storage batteries in cars contain quantities of lead, *(___). *symbol
Pb	58. The great weight of Pb, *(___), makes it undesirable for some uses. *name
lead	59. Natrium is the Latin word for sodium. The chemical symbol is (___).
Na	60. Ordinary table salt is Na, *(___), chloride. *name

sodium	61. Salt is essential to higher animals because they need sodium, *(___),compounds for their life processes. *symbol
Na	62. Sodium is very widely distributed in nature. The symbol for sodium is (___).
Na	63. Because it is such a very active metal Na, *(___), is never found free in nature. *name
sodium	64. The properties of Na, *(a), are very similar to potassium which the Romans called kalium. The symbol for potassium is (b). *name
a. sodium b. K	65. Potassium, *(a), is lighter than water. So is sodium, *(b). *symbol
a. K b. Na	66. Although phosphorus is pronounced with the "f" sound, its chemical symbol comes from the way you spell it. The symbol for phosphorus is (___).
P	67. Although potassium is pronounced with the "p" sound, its Latin name, "kalium," gives us its symbol, (___).
K	68. All plants require K, *(___). *name
potassium	69. An alloy of potassium, *(a), and sodium, *(b), is used in special thermometers. *symbol
a. K b. Na	70. Because they are valuable and relatively unreactive, gold, *(a), and silver, *(b), are known as noble metals. *symbol
a. Au b. Ag	71. The commonest dental fillings are mixtures called "amalgams" of silver, *(a), and mercury, *(b). *symbol
a. Ag b. Hg	72. Iron, *(a), is frequently protected fro corrosion by plating it with tin, *(b). *symbol
a. Fe b. Sn	73. Pewter is an alloy of copper, *(a), and tin, *(b). *symbol
a. Cu b. Sn	74. Zn is the symbol for (a). Sn is the symbol for (b).
a. Zinc b. Tin	

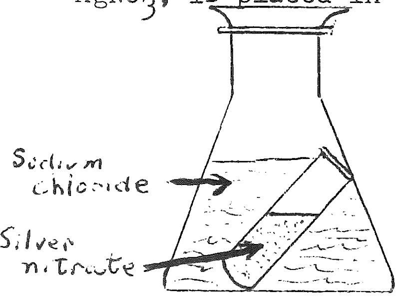
Student's name ______________________ School ______________ Sec. No. ______

PART 5

1a. ______________
1b. ______________
1c. ______________
2. ______________
3. ______________
4. ______________
5. ______________
6a. ______________
6b. ______________
7.. ______________
8. ______________
9. ______________
10. ______________
11. ______________
12a. ______________
12b. ______________
12c. ______________
12d. ______________
13a. ______________
13b. ______________
14a. ______________
14b. ______________
15a. ______________
15b. ______________
16. ______________
17. ______________
18. ______________
19. ______________
20. ______________
21. ______________
22. ______________
23. ______________
24a. ______________
24b. ______________
25a. ______________
25b. ______________
26. ______________
27a. ______________
27b. ______________
28. ______________
29. ______________
30. ______________
31a. ______________
31b. ______________
32. ______________
33. ______________
34. ______________
35. ______________
36. ______________
37. ______________
38. ______________
39. ______________
40. ______________
41. ______________
42. ______________
43. ______________
44a. ______________
44b. ______________
45. ______________
46a. ______________
46b. ______________
47. ______________
48. ______________
49. ______________
50a. ______________
50b. ______________
50c. ______________
51. ______________
52. ______________
53a. ______________
53b. ______________
54. ______________
55a. ______________
55b. ______________
56a. ______________
56b. ______________
57. ______________
58. ______________
59. ______________
60. ______________
61. ______________
62. ______________
63. ______________
64a. ______________
64b. ______________
65a. ______________
65b. ______________
66. ______________
67. ______________
68. ______________
69a. ______________
69b. ______________
70a. ______________
70b. ______________
71a. ______________
71b. ______________
72a. ______________
72b. ______________
73a. ______________
73b. ______________
74a. ______________
74b. ______________

PART 6

	1.	The chemical symbols are used in writing chemical formulas. A formula shows the kind and number of atoms present in a molecule of a compound. The chemical formula for a molecule of water is H_2O. The H tells you that the element *(___) is present in water. *name
hydrogen	2.	The O tells you that the element (___) is also present in water.
oxygen	3.	The number (or subscript) following the symbol of each element indicates how many atoms of that element are present in the molecule. The number 2 in H_2O tells us that there are two atoms of (___) in a molecule of water.
hydrogen	4.	If there is but a single atom of an element present in a molecule, chemists simply write the symbol of that element. They do not put the number one after the symbol. In H_2O, there is one atom of (___).
oxygen	5.	One molecule of table sugar has the formula, $C_{12}H_{22}O_{11}$. Thus, one molecule of sugar is made up of *(a) atoms of carbon, *(b) atoms of hydrogen, and *(c) atoms of oxygen. *how many?
a. 12 b. 22 c. 11	6.	A formula tells us the kind and (___) of atoms present in a molecule of a compound.
number	7.	All together, there are *(___) atoms in a molecule of sugar. *how many?
45	8.	Name each of the elements in NH_4Cl and after the name of each indicate how many atoms of the element are present in this molecule.
nitrogen-1 hydrogen-4 chlorine-1	9.	A formula tells us the (a) and (b) of atoms present in a molecule of a compound.
a. kind b. number	10.	One atom of sodium will combine with one atom of chlorine to form one molecule of sodium chloride. Since the combination of sodium and chlorine results in a new substance, it is a (___) change.
chemical	11.	Because sodium chloride is composed of two elements that are united chemically, it is a(n) (___).
compound	12.	According to the Law of Conservation of Matter, matter cannot be created or destroyed by ordinary chemical means. In the electrolysis of water, which is an ordinary chemical reaction, no matter is (a) or (b).

a. created b. destroyed (In any order)	13.	Matter is anything that has (a) and occupies (b).
a. weight b. space	14.	In the apparatus below, a solution of sodium chloride, $NaCl$, is put in the flask. A test tube of silver nitrate solution, $AgNO_3$, is placed in the flask. The flask is stoppered and weighed. The flask is then tipped upside down to mix the two solutions.  A chemical change takes place as a white substance is formed. This substance is silver chloride, $AgCl$, and it precipitates (settles to the bottom of the flask). The flask is weighed again and it weighs *(___) it did before the chemical change. *more than, less than, the same as
the same as	15.	Thus, no matter has been (a) or (b) in this chemical change.
a. created b. destroyed	16.	The experiment demonstrates the Law of (___) of Matter.
Conservation	17.	In the electrolysis of water, the weight of the hydrogen and oxygen formed is *(___) the weight of the water that is broken up. *less than, equal to, more than
equal to	18.	Therefore, no matter has been (a) or (b).
a. created b. destroyed	19.	The electrolysis of water illustrates the Law of (a) of (b).
a. Conservation b. Matter	20.	An equation is the chemist's way of writing what happens during a chemical reaction. The electrolysis reaction can be written: Water $\xrightarrow{\text{electricity}}$ Hydrogen + (___)
Oxygen	21.	Frame 20, above, is an example of a word equation. The expression, Iron + Sulfur $\xrightarrow{\text{heat}}$ Iron sulfide is also a *(___). *two words.
word equation	22.	The arrow (→) is read "produces," or "produce." Iron + Sulfur $\xrightarrow{\text{heat}}$ Iron sulfide is read iron and sulfur when heated (___) iron sulfide.
produce	23.	Water ⟶ Hydrogen + Oxygen The above word equation is read, water (___) hydrogen and oxygen.

produces	24.	Chemists prefer to use symbols and formulas instead of words when writing an equation. $Fe + S \xrightarrow{\triangle} FeS$ The above is a chemical equation. It is read, "one atom of iron and one atom of sulfur when heated produce one (___) of iron sulfide."
molecule	25.	The symbol, $\triangle$, means (___).
heat	26.	The electrolysis of water can be written, $2\ H_2O \longrightarrow 2\ H_2 + O_2$ The number "2" in front of H_2O indicates two molecules of water. The number "2" in front of H_2 indicates two molecules of hydrogen. There is no number in front of O_2. How many molecules of oxygen are formed? (___)
1	27.	The above equation is read, "two molecules of water (_a_) two molecules of (_b_) and one molecule of (_c_).
a. produce b. hydrogen c. oxygen	28.	The one molecule of oxygen is composed of how many atoms of oxygen? (_a_) Each molecule of hydrogen is composed of how many atoms of hydrogen? (_b_)
a. 2 b. 2	29.	Each molecule of water is composed of two atoms of (_a_) and one atom of (_b_).
a. hydrogen b. oxygen	30.	If one molecule of water contains 2 atoms of hydrogen and 1 atom of oxygen, then two molecules of water will contain (_a_) atoms of hydrogen and (_b_) atoms of oxygen.
a. 4 b. 2	31.	If one molecule of hydrogen is made up of 2 atoms of hydrogen, then two molecules of hydrogen is composed of (_a_) atoms of hydrogen. One molecule of oxygen contains (_b_) atoms of oxygen.
a. 4 b. 2	32.	$2\ H_2O \longrightarrow 2\ H_2 + O_2$ There are (_a_) atoms of hydrogen and (_b_) atoms of oxygen to the left of the arrow. There are (_c_) atoms of hydrogen and (_d_) atoms of oxygen to the right of the arrow.
a. 4 c. 4 b. 2 d. 2	33.	Since no new hydrogen and oxygen atoms were created by the reaction, and since none of the hydrogen and oxygen atoms were destroyed, the reaction illustrates the *(___). *five words
Law of Conservation of Matter	34.	According to the Law of Definite Proportions, every compound always has the same proportions by weight of the elements composing it. Several samples of water are weighed and then completely broken up into hydrogen and oxygen by electrolysis. In each case, the hydrogen and oxygen are also weighed.

(go on to next page)

	Weight of water	Weight of H_2	Weight of O_2
Sample A	9 grams	1 gram	8 grams
Sample B	18 grams	2 grams	16 grams
Sample C	27 grams	3 grams	24 grams
Sample D	45 grams	5 grams	40 grams

For each gram of hydrogen produced, (___) grams of oxygen are formed.

8

35. Water always contains 1 gram of hydrogen to every (___) grams of oxygen.

8

36. The proportion of hydrogen to oxygen by weight is 1 to (___).

8

37. Every compound always has the same proportions by (___) of the elements composing it, according to the Law of Definite Proportions.

---

weight

38. Four samples of iron sulfide were broken up into iron and sulfur.

	Weight of iron sulfide	Weight of iron	Weight of sulfur
Sample A	11 grams	7 grams	4 grams
Sample B	22 grams	14 grams	8 grams
Sample C	(a) grams	21 grams	(b) grams
Sample D	(c) grams	(d) grams	16 grams

---

a. 33 c. 44
b. 12 d. 28

39. All samples of iron sulfide are made up of seven parts by weight of iron and four parts by weight of sulfur. This illustrates the Law of *(___). *two words

---

Definite Proportions

40. Compound XY is divided into several samples. In the first sample, after breaking it down, you find 2 grams of X and 8 grams of Y.

Thus, in compound XY, for each gram of X there is (___) grams of Y.

4

41. The proportion of X to Y by weight in XY is 1 to (___).

4

42. Every compound always has the same (___) by weight of the elements composing it.

---

proportion

Student's Name______________________ School______________ Sec. No.______

PART 6

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

PART 7

	1. A solution is an example of a homogeneous mixture. It is a mixture in which the particles are evenly or uniformly mixed. Sugar dissolves in water to form a solution. This solution is a (___) mixture.
homogeneous	2. The solid (sugar) that is dissolved is called the solute. The liquid (water) in which the sugar is dissolved is called the solvent. When iodine particles dissolve in alcohol, the iodine is called the (a) and the alcohol is called the (b).
a. solute b. solvent	3. Since the iodine particles are evenly distributed or spread throughout the alcohol, the solution is a (___) mixture.
homogeneous	4. The iodine does not combine chemically with the alcohol to form a new substance. Therefore, the solution is not a (___).
compound	5. In certain drinks, such as "pop", carbon dioxide is dissolved in water. The carbon dioxide is the (a) and the water is the (b).
a. solute b. solvent	6. Alcohol will dissolve in water. Alcohol is the (a) and water is the (b).
a. solute b. solvent	7. The solution of alcohol in water is a homogeneous mixture. This means that the particles of alcohol and water are (___) distributed in each other.
evenly or uniformly	8. If substance A will dissolve in substance B, it is said to be soluble in B. If it will not dissolve, it is said to be insoluble in B. Sugar is (___) in water.
soluble	9. Iodine is (a) in alcohol and carbon dioxide is (b) in water.
a. soluble b. soluble	10. Oil will not dissolve in water. Therefore, oil is (___) in water.
insoluble	11. In solutions involving liquids and gases, such as the alcohol-water solution, it is difficult to determine which substance is the solute and which is the solvent unless you know more about the solution. Generally, the solute is the substance that is present in the smaller amount in a solution and the solvent is the substance present in the greater amount. If one pint of liquid A dissolves in one gallon of liquid B, liquid A is the (a) and liquid B is the (b).

a. solute b. solvent	12.	If 10 grams of nitrogen dissolve in 20 grams of oxygen, the oxygen is the (_a_) and the nitrogen is the (_b_).
a. solvent b. solute	13.	A solution is a *(___) of two substances. *two words
homogeneous mixture	14.	A saturated solution is one in which the solvent will not dissolve any more solute. If the solvent will dissolve more solute, the solution is said to be unsaturated. A spoonful of sugar is dissolved in water. A second spoonful of sugar is added and it also dissolves. The solution must have been (___).
unsaturated	15.	A third spoonful of sugar is added. Most of this sugar does not dissolve. Instead, it settles to the bottom of the container. The solution is now (___).
saturated	16.	If we heat a saturated solution of the sugar, we find that more sugar can be dissolved. This is true of most solutions composed of a solid *(_a_) and a liquid *(_b_). *solute or solvent
a. solute b. solvent	17.	Thus, most solids are *(___) soluble in hot solvents than in cold ones. *less or more
more	18.	Suppose you dissolve substance A (a solid) in substance B (a liquid). The temperature of substance B is 70° F. You continue adding substance A to the liquid until no more of it will dissolve. The solution is now (___).
saturated	19.	If you heat the solution to 90° F., more of substance A can be dissolved. The heated solution is (___).
unsaturated	20.	Whether a solution is saturated or unsaturated depends then on its (___).
temperature	21.	One gram of carbon dioxide (a gas) is dissolved in a container of water. If a second gram of carbon dioxide will also dissolve in the water, the solution must be (___).
unsaturated	22.	A third and a fourth gram of carbon dioxide are added to the water and they dissolve. However, when you attempt to add a fifth gram, you find that this will not dissolve. The solution, then, must be (___).
saturated	23.	If the carbon dioxide solution is heated, carbon dioxide gas will bubble out of the solution. You would guess, then, that gases are *(___) soluble in not solvents than in cold ones. *less or more

less	24.	On the other hand, if the carbon dioxide solution is cooled, more carbon dioxide can be dissolved. Apparently, gases are *(___) soluble in sold solvents than in hot ones. *less or more
more	25.	We can dissolve large amounts of gas in a liquid if we apply pressure to the solution. When we remove the cap from a bottle of pop, we *(___) the pressure on the solution. *decrease or increase
decrease	26.	With the cap removed, carbon dioxide bubbles out of the pop indicating that it is less soluble when the pressure is *(___). *decreased or increased
decreased	27.	The solubility of a gas in a liquid can be increased by *(a) the solvent and by **(b) the pressure. *cooling or heating **decreasing or increasing
a. cooling b. increasing	28.	Liquids that are not very soluble in each other form an emulsion. The liquid particles are not evenly distributed in each other. Therefore, an emulsion is a (___).
heterogeneous	29.	Since the particles in an emulsion are larger than those in a solution, they may settle out or separate. To prevent this from happening, an emulsifier may be added. Soap will prevent a kerosene and water solution from separating. The soap is a(n) (___).
emulsifier	30.	Solutions can be described as saturated or unsaturated. They can also be described as dilute or concentrated. A dilute solution is one that has a small amount of solute. A concentrated solution is one that has a large amount of solute. If you dissolved a spoonful of sugar in a quart of water, the solution would be (___).
dilute	31.	If you dissolved a cupful of sugar in a quart of water, the solution would be (___).
concentrated	32.	It is difficult to determine whether a solution is dilute or concentrated. How small is a "small amount of solute"? How large is a "large amount of solute"? Your idea of what is "small" or what is "large" may not be the same as that of your classmates. The terms "dilute" and "concentrated" *(___) very exact or definite terms. *are or are not
are not	33.	A mixture in which the particles are evenly distributed or uniformly mixed is said to be (___).

homogeneous	34.	A mixture in which the particles are not evenly or uniformly distributed or mixed is said to be (___).
heterogeneous	35.	A solution is a *(___) mixture. *heterogeneous or homogeneous
homogeneous	36.	An emulsion is a *(___) mixture. *heterogeneous or homogeneous
heterogeneous	37.	In a solution, the *(_a_) dissolves the *(_b_). *solute or solvent
a. solvent b. solute	38.	If substance A will not dissolve in substance B, substance A is said to be *(_a_) in B; if it will dissolve in substance B, substance A is said to be *(_b_) in B. *insoluble or soluble
a. insoluble b. soluble	39.	A spoonful of sugar is dissolved in a cup of coffee. The coffee will dissolve more sugar if it was added. The solution is *(___). *saturated or unsaturated
unsaturated	40.	The above solution might also be said to be *(___). *concentrated or dilute
dilute	41.	A cup of coffee is saturated with sugar. If the coffee is heated, *(___) can be dissolved in the coffee. *more sugar or no more sugar
more sugar	42.	A beaker of water is saturated with chlorine (a gas). If the water is heated, *(___) can be dissolved in the water. *more chlorine or no more chlorine
no more chlorine	43.	In fact, some of the chlorine that was dissolved in the water, will leave the solution when the water is (___).
heated		

Student's Name ______________________ School ______________ Sec. No. ____

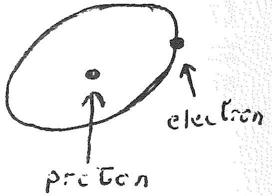
PART 7

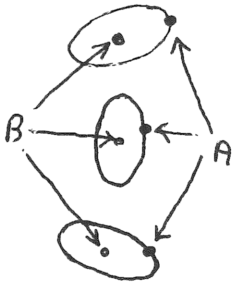
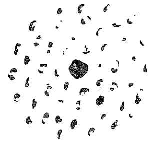
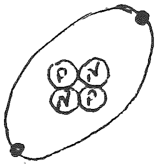
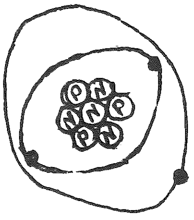
1. ______________
2a. ______________
2b. ______________
3. ______________
4. ______________
5a. ______________
5b. ______________
6a. ______________
6b. ______________
7. ______________
8. ______________
9a. ______________
9b. ______________
10. ______________
11a. ______________
11b. ______________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

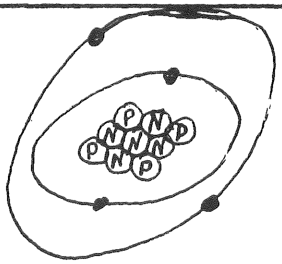
PART 8

	1. The smallest particle of an element that can combine chemically with other elements is called a(n)(___).
atom	2. Some of the early Greek scientists believed that matter was made of small particles called <u>atoms</u>, a word meaning indivisible. In 1803, John Dalton proposed the first useful or scientific <u>atomic theory</u>. According to Atomic Theory, all matter is made up of small particles that the Greeks called (___).
atoms	3. We said before that elements (which are matter) differ in their characteristics or qualities or (___).
properties	4. If this is true, then the smallest particle of one element must differ from the smallest particle of another element. We refer to these "smallest particles" as (___).
atoms	5. Thus, an atom of copper is *(___) an atom of lead. *different from or not different from
different from	6. The Atomic Theory also states that if you had a pure sample of any element, all of these small particles or atoms would be alike. In other words, an element contains only one kind of (___).
atom	7. All the atoms in a piece of pure iron *(___) all the same kind of atom. *are or are not
are	8. The atoms in a piece of pure aluminum *(___) all alike. *are or are not
are	9. If aluminum atoms were exactly like iron atoms, we would be unable to tell the two metals apart. Since we can tell the two metals apart you can be quite sure that the atoms in a piece of pure aluminum are *(___) the atoms in a piece of pure iron. *the same as or different from
different from	10. The atoms of one (_a_) differ from the atoms of another (_b_).
a. element b. element	11. Suppose John weighs 80 pounds and Joe weighs 120 pounds. Together, the two boys weigh (___) pounds.
200	12. If you divide the sum of their weights, 200 pounds, by 2 the answer or result is (___) pounds.
100	13. You would call the 100 pounds the (___) weight of the two boys.

average	14.	According to the Atomic Theory, the atoms of an element have a definite (___) weight.
average	15.	Let us suppose that the average weight of each aluminum atom is 27. (For the present, we will not label the weight. In other words, we will not call it 27 pounds or 27 grams, but just 27.) Suppose, also, that you have a sample of pure aluminum. If you weighed the sample and then divided the weight by the number of atoms in the sample, you would find that the average weight of each aluminum atom is (___).
27	16.	If you had a second sample of pure aluminum and repeated this procedure (weighed it and then divided the weight by the number of atoms in the sample), you would find that the average weight of each aluminum atom in the second sample is (___).
27	17.	Thus, the atoms of an element have a definite *(___). *two words
average weight	18.	Since an atom if iron is different from an atom of aluminum, you would guess that the average weight of an iron atom *(___) equal to the average weight of an aluminum atom. *is or is not
is not	19.	The average weight of an iron atom *(___) equal to the average weight of an oxygen atom. *is or is not
is not	20.	The average weight of the atoms of any element *(___) the average weight of the atoms of any other element. *is the same as or is different from
different from	21.	The first scientific Atomic Theory was proposed in 1803 by John (___).
Dalton	22.	The Atomic Theory states that: matter is made up of tiny particles called (a); there are as many different kinds of atoms as there are (b); atoms of an element have a definite (c) weight.
a. atoms b. elements c. average	23.	The Atomic Theory also states that atoms do not break up in ordinary chemical changes. When two atoms of hydrogen combine with one atom of oxygen to form one molecule of water, the hydrogen and oxygen atoms *(___) broken up into smaller particles. *are or are not
are not	24.	When iron atoms combine with sulfur atoms to form iron sulfide (an ordinary chemical change), the iron atoms *(___) broken up into smaller particles. *are or are not

are not	25.	Each atom of iron in iron sulfide *(___) like every other iron atom. *is or is not
is	26.	The smallest particle of an element that can combine chemically with other elements is called a(n) (___).
atom	27.	Since there are 104 elements, there are at least 104 different kinds of (___).
atoms	28.	A nitrogen atom is *(___) a nickel atom. *like or different than
different than	29.	All the atoms in a bar of pure copper are very *(___). *similar or different
similar	30.	Atoms of an element have a definite (___) weight.
average	31.	If you had two samples of oxygen, each containing the same number of atoms, you would expect each sample to have *(___) weight. *a different or the same
the same	32.	If you had a sample of oxygen and a sample of hydrogen, each sample containing the same number of atoms, you would expect the samples to have *(___) weight. *a different or the same
a different	33.	The Atomic Theory was proposed in 1803 by (___).
John Dalton	34.	The Atomic Theory states that: (1)matter is made up of tiny particles called (_a_). (2)there are as many different kinds of atoms as there are (_b_). (3)atoms of an element have a definite (_c_) weight. (4)atoms of different elements have different average (_d_). (5)atoms do not break up in ordinary (_e_) changes.
a. atoms b. elements c. average d. weights e. chemical	35.	Atoms are made up of many smaller particles, but the three basic particles are called electrons, protons, and neutrons. The electrons and protons are electrically charged. The (___) is uncharged or neutral.
neutron	36.	The simplest atom is that of ordinary hydrogen. The basic particle that is missing in the hydrogen atom is the (___). 
neutron	37.	In the hydrogen atom, the (___) travels in a path around the proton.
electron	38.	The path that a space ship follows in its journey around the earth is called a(n) (___).

orbit	39. Likewise, the path that the electron follows in its trip around the proton, in the hydrogen atom, is sometimes called its (___).
orbit	40. Just as the orbit of a space ship changes with each trip around the earth, so the orbit of the hydrogen electron also changes with each trip around the proton. In the diagrams, arrow A points to the (a) and arrow B to the (b). 
a. electron b. proton	41. Suppose that the hydrogen atom was large enough so that you could take a picture of it. Suppose further that you took a picture of the atom every second for an hour and that you then combined all the pictures into a single picture. It would probably look like the diagram. Since the (___) was moving, its position changed each second. 
electron	42. Thus, the electron occupies many different positions during the hour. On the one large picture, the area outside the proton would be rather hazy. Scientists call this area the electron cloud or shell. The electron cloud or shell, then, is that area in which one would find the atomic particle called the (___).
electron	43. The helium atom is diagrammed below. "P" stands for proton and "N" for neutron. An electron is shown by a dot, ● . The helium atom has *(a) electron(s), *(b) proton(s), and *(c) neutron(s). *how many? 
a. 2 b. 2 c. 2	44. The center of the atom is called the nucleus. In the helium atom, the nucleus is made up of two (a) and two (b).
a. protons b. neutrons (In any order)	45. The two helium electrons travel around the nucleus in the same orbit, or electron cloud, or (___).
shell	46. The diagram to the right is of the lithium atom. It is composed of *(a) electron(s), *(b) proton(s), and *(c) neutron(s). *how many? 
a. 3 b. 3 c. 4	47. The protons and neutrons together make up that part of the atom called the (___).

nucleus	48.	The electrons in the lithium atom travel in two different (___).
orbits or shells	49.	Scientists sometimes refer to the orbits by still another name, <u>energy levels</u>. Thus, in the case of lithium, the electrons are found in *(___) energy levels. *how many?
2	50.	The beryllium atom is made up of *(_a_) electron(s), *(_b_) proton(s), and *(_c_) neutron(s). 
a. 4 b. 4 c. 5	51.	Nine particles are found in the (___) of the beryllium atom.
nucleus	52.	The four electrons of the beryllium atom travel in two different orbits, or shells, or (___) levels.
energy		

Student's Name ______________________________ School ____________________ Sec. No. _____

PART 8

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________
6. ____________________
7. ____________________
8. ____________________
9. ____________________
10a. ____________________
10b. ____________________
11. ____________________
12. ____________________
13. ____________________
14. ____________________
15. ____________________
16. ____________________
17. ____________________
18. ____________________
19. ____________________
20. ____________________
21. ____________________
22a. ____________________
22b. ____________________
22c. ____________________
23. ____________________
24. ____________________
25. ____________________
26. ____________________
27. ____________________
28. ____________________
29. ____________________
30. ____________________
31. ____________________
32. ____________________
33. ____________________
34a. ____________________
34b. ____________________
34c. ____________________
34d. ____________________
34e. ____________________
35. ____________________
36. ____________________
37. ____________________
38. ____________________
39. ____________________
40a. ____________________
40b. ____________________
41. ____________________
42. ____________________
43a. ____________________
43b. ____________________
43c. ____________________
44a. ____________________
44b. ____________________
45. ____________________
46a. ____________________
46b. ____________________
46c. ____________________
47. ____________________
48. ____________________
49. ____________________
50a. ____________________
50b. ____________________
50c. ____________________
51. ____________________
52. ____________________

PART 9

1\. The three basic particles that make up an atom are the (_a_), (_b_), and (_c_).

a. electron
b. proton
c. neutron
(In any order)

2\. The central part of an atom is called the (___).

nucleus

3\. The nucleus is made up of two basic particles, the (_a_) and the (_b_).

a. proton
b. neutron
(In any order)

4\. The electrons travel around the nucleus in paths called orbits, or (_b_), or *(_c_). *two words

b. shells
c. energy levels

5\. Up until now, we have said that the words "orbit", "shell" and "energy level" all refer to the path the electrons travel in around the nucleus. Generally, there is a circular orbit or path located near to the nucleus. Somewhat further out (away from the nucleus) there are four paths or orbits. All of these are about the same distance from the nucleus, but they differ in shape. We refer to this group of 4 paths or orbits as a shell or energy level. We also refer to that single path near the nucleus as a (_a_) or (_b_).

a. shell
b. energy level
(In any order)

Element	Electrons	Neutrons	Protons
Hydrogen	1	0	1
Helium	2	2	2
Lithium	3	4	3
Beryllium	4	5	4
Boron	5	6	5
Carbon	6	6	6
Nitrogen	7	7	7

6\. In the case of each element above, the number of electrons in the atom is equal to the number of (___).

protons

7\. No two elements above have the same number of (___).

electrons or protons

8\. The atomic number of an element is the number of protons contained in the nucleus of its atom.

The atomic number of hydrogen is *(___). *number

1

9\. The atomic number of lithium is *(___). *number

3

10\. The atomic number of carbon is (___).

6

11\. The electron carries a negative or minus electrical charge. The proton carries a positive or plus electrical charge. The two charges are equal to each other, but opposite.

We indicate the charge on one electron by writing -1. We indicate the charge on one proton by writing (___).

+1	12.	The helium atom is made up of 2 electrons, 2 protons, and 2 neutrons. Which of the three basic particles does not carry an electrical charge? (___)
neutron	13.	We would indicate the total negative charge on the two electrons in the helium atom by multiplying the number of electrons by -1, the charge on one electron. 2 X (-1) = -2 The carbon atom has 6 electrons. The total negative charge of the six carbon electrons is (___).
-6 (6 X -1 = -6)	14.	Boron's atom has 5 electrons. The total charge on these electrons is (___).
-5	15.	To find the total positive charge on the protons of an atom, we multiply the number of protons times +1, the charge on one proton. Since the helium atom has two protons, the total positive charge on these particles is: 2 X (+1) = +2 What is the total positive charge on the six protons in the carbon atom? (___)
+6	16.	The boron atom has 5 protons. The total positive charge on these protons is (___).
+5	17.	The hydrogen atom is made up of one electron (-1) and one proton (+1). The two charges are opposite in sign, but equal in strength. They cancel each other and the total charge on the hydrogen atom is: -1 +1 0 You have learned (in Algebra I) that when you add two numbers with opposite signs that you subtract the small number from the larger number and give your answer the same sign as the larger number. Thus, if you add +4 and -2, the answer is (___).
+2	18.	The helium atom has 2 electrons and 2 protons. The total charge on the atom is: -2 +2 (___)
0	19.	The carbon atom has 6 electrons and 6 protons. The total charge on the electrons is 6 X -1 = -6; the total charge on the protons is 6 X +1 = +6. The total charge on the carbon atom is: -6 +6 (___)
0	20.	The oxygen atom has 8 electrons and 8 protons. The total charge on the atom is (___).
0	21.	The number of electrons in any atom is *(___) the number of protons in the atom. *equal to or different from

equal to	22.	Since the number of electrons in an atom is equal to the number of protons, the total charge on any atom is *(___). *number
0	23.	The <u>atomic particle</u> that has a +1 charge is the (___).
proton	24.	The atomic particle that has no charge is the (___).
neutron	25.	Of the three basic atomic particles, the electron is the lightest. A proton weighs about 1840 times as much as an electron. A neutron also weights about (___) times as much as an electron.
1840	26.	If we say that an electron weighs 1 g.f. (grand forks), then one proton weighs (___) g.f.
1840	27.	One neutron weighs 1840 (___).
g.f.	28.	The helium atom is made up of 2 electrons, 2 protons, and 2 neutrons. Its total weight is: 2 electrons X 1 g.f. = 2 g.f. 2 protons X 1840 g.f. = 3680 g.f. 2 neutrons X 1840 g.f. = 3680 g.f. 7362 g.f. The 2 protons and 2 neutrons are found in the center or (___) of the helium atom.
nucleus	29.	As you can see from Frame #28, almost all the weight of the helium atom is found in the (___).
nucleus	30.	Since it is so light, we can disregard or forget about the weight of which atomic particle? (___)
electron	31.	If we continued to work with the g.f. as our unit of weight, we would have to work with very large numbers as the atoms increased in size. For example, gold has 79 electrons, 79 protons, and 118 neutrons. It weighs 362,559 g.f. Let us change our unit of weight and say that one proton weighs 1 a.w.u. (atomic weight unit). The weight of one neutron will also be (___) a.w.u.
1	32.	In figuring the weight of an atom we will disregard the weight of the (___).
electron	33.	Using our new weight unit, we find that the helium atom of Frame #28 weighs: 2 protons X 1 a.w.u. = 2 a.w.u. 2 neutrons X 1 a.w.u. = 2 a.w.u. 4 a.w.u. The gold atom of Frame #31 will weigh (___) a.w.u.
197 (79 protons + 118 neutrons)	34.	The nitrogen atom (7 electrons, 7 protons, and 7 neutrons) will weigh (___) a.w.u.

14	35. The hydrogen atom (1 electron and 1 proton) will weigh 1 (___).
a.w.u.	36. The neon atom is made up of 10 electrons, 10 protons, and 10 neutrons. The total charge on the atom is (_a_) and the weight of the atom is (_b_).
a. 0 b. 20 a.w.u.	37. The atomic weight unit (a.w.u.) is equal to the weight of one (_a_) or one (_b_). Both of these particles are found in the nucleus.
a. proton b. neutron (In any order)	38. The actual weight of a hydrogen atom is about 0.000,000,000,000,000,000,000,000,06 of an ounce. The weight of any other atom would also be very, very (___).
small	39. Working with such small numbers would be very difficult. Therefore, chemists decided to consider the weight of a carbon atom to be 12 a.w.u. The abbreviation, a.w.u., stands for *(___). *three words
atomic weight unit	40. The weight of a hydrogen atom is about 1/12 that of a carbon atom. Thus, the atomic weight of hydrogen is $\frac{1}{12}$ X 12 = (___)
1	41. The weight of a magnesium atom is twice that of a carbon atom; thus, the atomic weight of magnesium is: 2 X 12 = (___)
24	42. The atomic weight of any element is the average weight of its atoms compared to the average weight of the (___) atom.
carbon	43. The atomic weight of an element can be found in two ways. First, you can compare the average weight of its atoms to the weight of a (___) atom.
carbon	44. Or, secondly, you can add the number of protons and neutrons in the atom's (___).
nucleus	45. Let us try both ways with the oxygen atom. The average oxygen atom weighs 4/3 as much as the carbon atom. The atomic weight of oxygen is: $\frac{4}{3}$ X 12 = (___)
16	46. The oxygen atom has 8 protons and 8 neutrons. Adding the number of protons and neutrons gives you the atomic weight of oxygen, which is (___).
16	47. We said earlier that the <u>atomic number</u> of an element is the number of (___) in the nucleus of its atom.

protons	48.	We also said that if you add the number of protons and neutrons in the nucleus of an atom, you can determine the atomic (___) of the element.
weight	49.	The atomic number of tin in 50. This means that there are 50 (___) in the nucleus of a tin atom.
protons	50.	The atomic weight of tin in 119. This means that the sum of the (a) and (b) in the nucleus of the tin atom is 119.
a. protons b. neutrons (In any order)	51.	The atomic weight of 119 tells you that there are 119 particles (protons + neutrons) in the nucleus of the tin atom. The atomic number of 50 tells you that 50 of these particles are protons. Therefore, 119 minus 50 must equal the number of neutrons. There are 119 - 50 neutrons in the nucleus. 119 - 50 = (___)
69	52.	The atomic number of sodium is 11 and its atomic weight is 23. How many neutrons are there in the nucleus of the sodium atom? (___)
12		

Student's Name______________________________ School________________ Sec. No._______

PART 9

1a. ____________________

1b. ____________________

1c. ____________________

2. ____________________

3a. ____________________

3b. ____________________

4b. ____________________

4c. ____________________

5a. ____________________

5b. ____________________

6. ____________________

7. ____________________

8. ____________________

9. ____________________

10. ____________________

11. ____________________

12. ____________________

13. ____________________

14. ____________________

15. ____________________

16. ____________________

17. ____________________

18. ____________________

19. ____________________

20. ____________________

21. ____________________

22. ____________________

23. ____________________

24. ____________________

25. ____________________

26. ____________________

27. ____________________

28. ____________________

29. ____________________

30. ____________________

31. ____________________

32. ____________________

33. ____________________

34. ____________________

35. ____________________

36a. ____________________

36b. ____________________

37a. ____________________

37b. ____________________

38. ____________________

39. ____________________

40. ____________________

41. ____________________

42. ____________________

43. ____________________

44. ____________________

45. ____________________

46. ____________________

47. ____________________

48. ____________________

49. ____________________

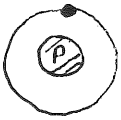
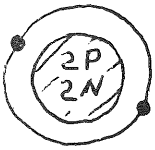
50a. ____________________

50b. ____________________

51. ____________________

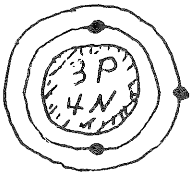
52. ____________________

PART 10

	1.	Let us review. The three main basic particles that make up an atom are the (_a_), (_b_), and (_c_).
a. electron b. proton c. neutron (In any order)	2.	The neutron is neutral. The (_a_) has a +1 charge and the (_b_) has a -1 charge.
a. proton b. electron	3.	The center of an atom is called the (___).
nucleus	4.	The two kinds of atomic particles found in the nucleus are the (_a_) and the (_b_).
a. protons b. neutrons (In any order)	5.	The atomic (___) of an element is the number of protons in the nucleus of an atom of that element.
number	6.	The atomic weight of an element is the average weight of its atoms compared to the average weight of a (___) atom, which is 12.
carbon	7.	To find out how many (___) are in the nucleus of an atom, subtract the element's atomic number from its atomic weight.
neutrons	8.	The electrons of an atom travel around the nucleus in paths called orbits. A number of orbits may be grouped together into (_a_) or (_b_) levels.
a. shells b. energy	9.	Below is a diagram of the hydrogen atom. The dot stands for one electron and the letter "P" stands for one proton. The electron orbit is shown somewhat differently than it was shown before.  The hydrogen atom has *(___) proton(s) in the nucleus. *how many?
1	10.	There are seven different shells or energy levels which the electrons may be found in. Each is located at a different distance from the nucleus. The shell nearest to the nucleus is called the K shell or the first (1st) energy level. The K shell of the helium atom is completely filled--it is holding all the electrons that a K shell can hold. How many electrons does the helium atom have in the K shell? (__) 
2	11.	Another name for the K shell is the 1st *(___). *two words
energy level	12.	The maximum (most) number of electrons that an atom can have in the 1st energy level is *(___). *how many? Hint: how many did the helium atom have?

2

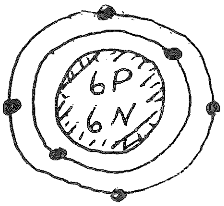
13. The lithium atom has 3 electrons. Two of these electrons are found in the (_a_) shell or (_b_) energy level.



a. K
b. 1st

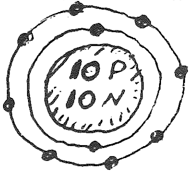
14. The third electron is found in the L shell or 2nd energy level.

The carbon atom pictured to the right has 6 electrons. How many electrons does it have in the L shell or 2nd energy level? (___)



4

15. The maximum (most) number of electrons that the L shell or 2nd energy level can hold is 8. Below is a diagram of the neon atom.
Its atomic number is (_a_) and its atomic weight is (_b_).



a. 10 (number of protons)
b. 20 (protons + neutrons)

16. Chemists have found that the L shell or 2nd energy level is made up of 2 sub-shells. The first sub-shell can hold 1 or 2 electrons which travel in a circular path around the central part of the atom. The central part of the atom is called the (___).

nucleus

17. In the second sub-shell, electrons can travel in three different paths around the nucleus. The paths are not circular. They are oval (egg-shaped). These paths are called orbitals.

There are 3 (___) in the second sub-shell of the 2nd energy level.

orbitals

18. Each orbital can hold 1 or 2 electrons--no more than 2. The maximum (most) number of electrons that can be present in the 3 orbitals of the second sub-shell is *(___). *how many?

6 (3 X 2)

19. Let us break down the 2nd energy level or L shell once again.

First sub-shell....1 orbital...can hold 2 electrons
Second sub-shell...3 orbitals..can hold 6 electrons

Altogether, in the 2nd energy level or L shell, one may find a total of *(_a_) orbitals and a total of *(_b_) electrons. *how many?

a. 4
b. 8

Element	No. of electrons in K shell	No. of electrons in L shell
Hydrogen	1	0
Helium	2	0
Lithium	2	1
Beryllium	2	2
Boron	2	3
Carbon	2	4
Nitrogen	2	5
Oxygen	2	6
Fluorine	2	7
Neon	2	8

20. Can the L shell hold less than 8 electrons? (___)

Yes

21. If an atom had both the K and L shells completely filled with electrons (see Neon above), it would have a total of *(___) electrons. *how many?

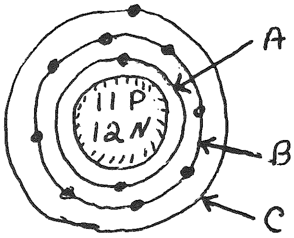
10

22. The sodium atom has 11 electrons. It is pictured below.

Arrow A points to the (_a_) shell or (_b_) energy level.

Arrow B points to the (_c_) shell or the (_d_) energy level.

Arrow C points to the (_e_) or (_f_) energy level.



a. K
b. 1st
c. L
d. 2nd
e. M
f. 3rd

23. The M shell or 3rd energy level is composed of three sub-shells. The first sub-shell, like the first sub-shell of the 2nd energy level, can hold a maximum of *(___) electrons. *how many?

2

24. The second sub-shell, like the second sub-shell of the 2nd energy level, can hold a maximum of (___) electrons.

6

25. As you noted, the second sub-shell can hold 4 more electrons than the first sub-shell. (The second sub-shell can hold 6 electrons while the first sub-shell can hold 2).

The third sub-shell can hold 4 more electrons than the second sub-shell. Thus, it can hold (___) electrons, altogether.

10 (6 + 4)

26. The first sub-shell can hold 2 electrons, the second sub-shell can hold 6, and the third sub-shell can hold 10. If an atom had all of these sub-shells completely filled with electrons, it would have how many electrons in the M shell? (___)

18 (2 + 6 + 10)

27. If an atom had the K shell, the L shell, and the M shell completely filled with electrons, it would have a total of *(___) electrons. *how many

28 (2 + 8 + 18)	28.	We said that the 1st energy level or K shell can hold a maximum of (_a_) electrons; the 2nd energy level or L shell can hold a maximum of (_b_) electrons, and the 3rd energy level or M shell can hold a maximum of (_c_) electrons.
a. 2 b. 8 c. 18	29.	There is a mathematical formula that you can use to determine the maximum number of electrons that a given energy level can hold. It is: Maximum number of electrons = $2L^2$ The "L" stands for the number of the energy level. To find the maximum number of electrons that the 1st energy level can hold, replace the "L" with a 1. 1 squared is 1 X 1 = 1; and 2 X 1 = 2. To find the maximum number of electrons that the 2nd energy level can hold, you would replace the "L" with the number (___).
2	30.	Let us use the formula, $2L^2$, to determine the maximum number of electrons that the 2nd energy level or L shell can hold. Replacing the "L" in the formula with a 2 (2nd energy level), we find that 2 squared is 2 X 2 = 4. Multiplying 4 by 2 gives us a maximum of 8 electrons. To find the maximum number of electrons that the 3rd energy level or M shell can hold, you would replace the "L" with the number (___).
3	31.	Completing the problem: $2L^2$ = 2(3 X 3) = 2 X 9 = 18, the maximum number of electrons that the 3rd energy level can hold. What is the maximum number of electrons that the 4th energy level or N shell can hold? (___)
32 (2 X 4^2 = 2 X 16)	32.	The 4th energy level is also called the (___) shell.
N	33.	The O shell is also known as the 5th *(___). *two words
energy level	34.	The 6th energy level is also known as the (___) shell.
P	35.	The Q shell is also known as the *(___). *three words
7th energy level		

Student's Name______________________ School______________ Sec.No.______

PART 10

1a. ______________________

1b. ______________________

1c. ______________________

2a. ______________________

2b. ______________________

3. ______________________

4a. ______________________

4b. ______________________

5. ______________________

6. ______________________

7. ______________________

8a. ______________________

8b. ______________________

9. ______________________

10. ______________________

11. ______________________

12. ______________________

13a. ______________________

13b. ______________________

14. ______________________

15a. ______________________

15b. ______________________

16. ______________________

17. ______________________

18. ______________________

19a. ______________________

19b. ______________________

20. ______________________

21. ______________________

22a. ______________________

22b. ______________________

22c. ______________________

22d. ______________________

22e. ______________________

22f. ______________________

23. ______________________

24. ______________________

25. ______________________

26. ______________________

27. ______________________

28a. ______________________

28b. ______________________

28c. ______________________

29. ______________________

30. ______________________

31. ______________________

32. ______________________

33. ______________________

34. ______________________

35. ______________________

PART 11

1. Chemists have found it convenient to classify the elements in the order of their atomic numbers. Such a classification is pictured on page 620 of your textbook. It is called a PERIODIC TABLE.

Use the Table to answer the frames that follow.

The seven horizontal rows of the Table are called (___).

Periods

2. The Periodic Table contains 18 columns or vertical rows. These are called (___).

Groups

3. One element has been placed all by itself at the top of the Table. That element is (___).

hydrogen

4. The period numbers (1 through 7) represent the energy levels or shells in which the electrons are found. As you can note, hydrogen (H) and helium (He) are found in Period Number 1. This tells you that the outermost electrons (the ones furthest from the nucleus) of hydrogen and helium are found in the 1st energy level or (___) shell.

K

5. The outermost electrons of all the elements in Period Number 2 will be found in the (___) energy level.

2nd

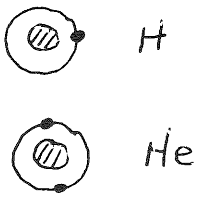
6. The top number in each small square tells you the atomic number of that element. The atomic number is the number of (___) in the nucleus of the atom.

protons

7. The atomic number also tells you the number of (___) that are orbiting around the nucleus.

electrons

8. Thus, hydrogen (H) has 1 electron and helium (He) has 2 electrons.

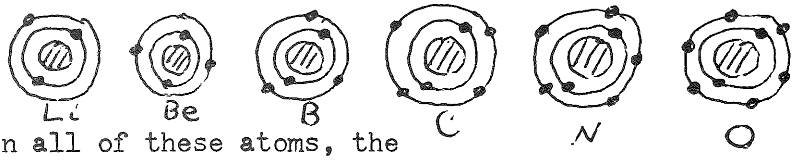


In the case of both of these atoms, electrons are found only in the (a) shell or *(b).

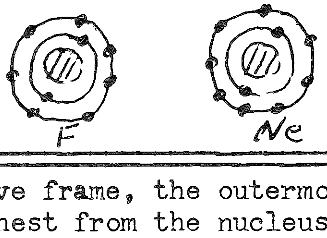
*three words

a. K
b. 1st energy level

9. The elements in Period Number 2 are diagrammed below.



In all of these atoms, the (a) shell or *(b) is completely filled with electrons.



*three words

a. K
b. 1st energy level

10. In all of the atoms in the above frame, the outermost electron (the one that is furthest from the nucleus) is found in the (a) shell or *(b).

*three words

a. L
b. 2nd energy level

11. Thus, the period number (2) tells you that the outermost electron in the atoms of the 8 elements in this period is found in the L shell or (___) energy level.

2nd

12. Note that the period number (2) is identical (the same as) the number of the energy level in which the outermost electron is found; in this case, the 2nd energy level.

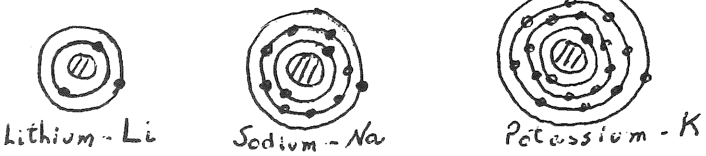
You would guess than that the outermost electron in the atoms of the elements in period number 3 will be found in the (_a_) shell or (_b_) energy level.

a. M
b. 3rd

13. You would also guess that the outer electrons of the elements in Period Number 4 will be found in the (_a_) energy level or (_b_) shell.

a. 4th
b. N

14. Let us take a look at the columns, starting with column IA. The first three elements in that column are diagrammed below.



Each of these atoms has *(___) electron(s) in its outer shell.
*how many?

1

15. The other three elements in this column (rubidium, Rb; cesium, Cs; and francium, Fr) also have *(___) electron(s) in their outer shell. *how many?

1

16. We said earlier that atoms are neutral. The total charge on the atom is 0 since the number of protons in the atom is equal to the number of (___).

electrons

17. Chemists have found that the elements in column IA will give up or lose their outer electron in chemical reactions. After an atom has given up or lost an electron, it is no longer neutral. In fact, it is no longer called an atom; but, instead, it is called an ion.

The lithium atom has 3 protons and 3 electrons. After it loses its outer electron, it has 3 protons and only 2 electrons. It is no longer a lithium atom; it is now a lithium (___).

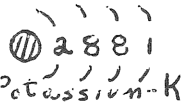
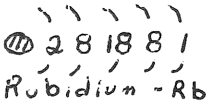
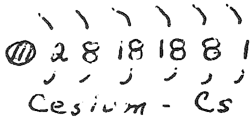
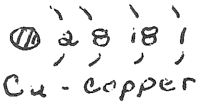
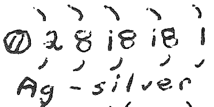
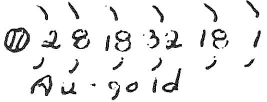
ion

18. The lithium ion has 3 protons and 2 electrons. Its total charge is:

$$\begin{array}{r} +3 \\ \underline{-2} \\ +1 \end{array}$$

Remember: to add signed numbers, subtract the smaller number from the larger one and give the answer the same sign as the larger number.

The sodium ion has 11 protons and 10 electrons. What is its charge? (___)

+1	19. All of the elements in column IA will *(___) an electron during a chemical reaction. *gain or lose
lose	20. After an atom has lost an electron, it is no longer called a(n) (_a_); but, rather, it is called a(n) (_b_).
a. atom b. ion	21. Like the lithium ion and the sodium ion, the ions of the elements in column IA have a charge of (___).
+1	22. Chemists often refer to the charge on an ion as the <u>valence number</u> of the element. Since the lithium ion has a charge of +1, the *(___) of lithium is +1. *two words
valence number	23. All of the elements in column IA have a *(___) of +1. *two words
valence number	24. Up until now, in our diagrams of atoms, we have drawn a dot for each electron. In the larger atoms, those with many electrons, this is often awkward. Below are diagrams of three of the elements of column IA which have large atoms. The numbers indicate the number of electrons in each shell.    How many electrons do each of these elements have in the shell <u>next</u> to the outer shell? (___)
8	25. Find column IB in the Periodic Table. The three elements in this column are diagrammed below.    Each of these atoms has *(_a_) electron(s) in its outer shell and *(_b_) electron(s) in the shell next to the outer shell. *how many?
a. 1 b. 18	26. Like the elements of column IA, the elements of column IB have *(___) electron(s) in the outer shell. *how many?
1	27. The elements in the two columns differ in that the elements of column IB have (_a_) electrons in the shell next to the outer shell, while the elements of column IA have (_b_) electrons in this shell.
a. 18 b. 8	28. We said before that the elements in column IA will give up their outer electron in most chemical reactions. Thus, they have a valence number of (___).
+1	29. The elements in column IB also have one electron in the outer shell. They will give up this outer electron in chemical reactions. Therefore, they also have a valence number of (___).

+1

30. Copper, Cu, in some reactions, will give up its outer electron and one electron from its M shell or 3rd energy level. Thus, it loses two electrons in these chemical reactions.

The copper ion that results has 29 protons and 27 electrons (having lost 2 electrons). Its total charge is (+29) + (-27) = +2. Therefore, the (___) of this ion is also +2.

valence number

31. The copper ion with a +1 valence number is known as the cuprous or copper I ion.

The copper ion with a +2 valence number is known as the cupric or copper II ion.

The copper ion whose name ends in *(___) has the lower or smaller valence number. *last three letters

ous

32. The chart below lists the more common elements of columns IA and IB and their valence numbers. Fill in the missing valence numbers.

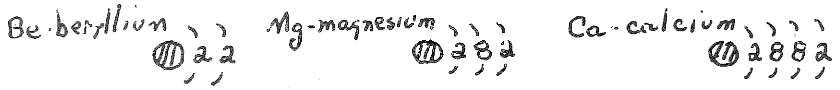
Column IA	Column IB
Lithium (Li).....+1	Copper (Cu)....+1 or (_a_)
Sodium (Na)......+1	Silver (Ag)....+1
Potassium (K)...(_b_)	

a. +2
b. +1

33. The cupric ion or copper II ion has a valence number of (___).

+2

34. The first three elements in column IIA are diagrammed below.



Each of the elements have *(___) electrons in its outer shell. *how many?

2

35. The same is true of the other three elements in column IIA (strontium, Sr; barium, Ba; and Radium, Ra). All of the elements in this column have 2 electrons in the (___) shell.

outer

36. The elements in column IIA will usually give up or lose both of these outer electrons in chemical reactions.

The beryllium atom has 4 protons and 4 electrons. The beryllium ion has (_a_) protons and (_b_) electrons.

a. 4
b. 2

37. The magnesium atom has 12 protons and 12 electrons. The magnesium ion has (_a_) protons and (_b_) electrons.

a. 12
b. 10

38. The beryllium ion has a charge of: (+4) + (-2) = +2. Thus, the valence number of beryllium is (___).

+2

39. The magnesium ion has a charge of: (+12) + (-10) = +2. Thus, the *(___) number of magnesium is +2.

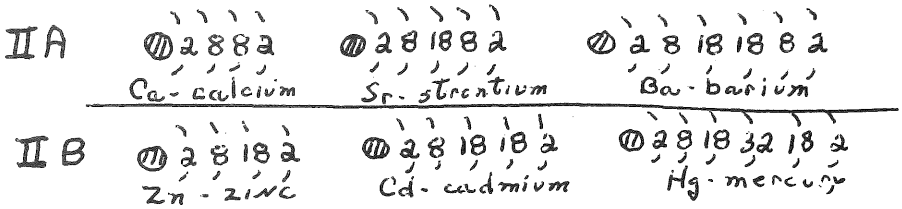
*two words

valence number

40. Since all of the elements in column IIA lose 2 electrons in chemical reactions, the valence number of each of these elements is (___).

+2

41. Three atoms from column IIA and three from column IIB are diagrammed below.



Each of these atoms has *(___) electrons in the outer shell. *how many?

2

42. The elements in column IIA have *(a) electrons in the shell next to the outer shell.
The elements in column IIB have *(b) electrons in the shell next to the outer shell. *how many

a. 8
b. 18

43. Since all of the elements in columns IIA and IIB have two electrons in the outer shell which can be given away in chemical reactions, their valence number is (___).

+2

44. One element in these two columns that is an exception is mercury, Hg. In some reactions, mercury gives up only one of its outer electrons. The mercury ion that is formed in these reactions is known as the <u>mercurous</u> or mercury I ion and it has a valence number of +1.

When the mercury atom gives up both outer electrons, the ion that is formed is called the <u>mercuric</u> or mercury II ion and its valence number is (___).

+2

45. The name of the mercury ion with the lower or smaller valence number ends in *(___). *last 3 letters

ous

46. The chart below lists the more common elements of columns IIA and IIB and their valence numbers. Fill in the missing valence numbers.

Column IIA		Column IIB	
Beryllium (Be).....	+2	Zinc (Zn)........	+2
Magnesium (Mg).....	+2	Cadmium (Cd).....	+2
Calcium (Ca).......	(a)	Mercury (Hg).....	+2 or (b)
Strontium (Sr).....	+2		
Barium (Ba)........	(c)		

a. +2
b. +1
c. +2

47. Note: the elements in the two columns headed by Roman numeral I have 1 electron in their outer shells. The elements in the two columns headed by Roman numeral II have (___) electron(s) in their outer shells.

2

48. Thus, the Roman numeral tells you how many electrons are in the *(___) of the elements in the columns. *two words

outer shell

Student's Name____________________ School______________ Sec. No.______

PART 11

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________
6. ____________________
7. ____________________
8a. ____________________
8b. ____________________
9a. ____________________
9b. ____________________
10a. ____________________
10b. ____________________
11. ____________________
12a. ____________________
12b. ____________________
13a. ____________________
13b. ____________________
14. ____________________
15. ____________________
16. ____________________
17. ____________________
18. ____________________
19. ____________________
20a. ____________________
20b. ____________________
21. ____________________
22. ____________________
23. ____________________
24. ____________________
25a. ____________________
25b. ____________________
26. ____________________
27a. ____________________
27b. ____________________
28. ____________________
29. ____________________
30. ____________________
31. ____________________
32a. ____________________
32b. ____________________
33. ____________________
34. ____________________
35. ____________________
36a. ____________________
36b. ____________________
37a. ____________________
37b. ____________________
38. ____________________
39. ____________________
40. ____________________
41. ____________________
42a. ____________________
42b. ____________________
43. ____________________
44. ____________________
45. ____________________
46a. ____________________
46b. ____________________
46c. ____________________
47. ____________________
48. ____________________

PART 12

	1. We have been working with a classification of the elements based on their atomic numbers. This chart is called the *(___). *two words
Periodic Table	2. The element potassium is found in the Periodic Table in column IA and in Period Number #3. This tells you that the potassium atom has (_a_) electron(s) in the outer shell and that the outermost electron(s) will be found in the (_b_) shell or (_c_) energy level.
a. 1 b. M c. 3rd	3. Because it has one electron in its outer shell, potassium has a valence number of (___).
+1	4. The only element in columns IIIA and IIIB with which we are concerned in this course is aluminum, Al. It has 3 electrons in its outer shell. Its valence number is (___).
+3	5. The elements in solumns IVA and IVB have *(___) electrons in their outer shell. *how many?
4	6. One would guess that these elements will give up these outer electrons in chemical reactions and, therefore, that their valence number is (___).
+4	7. It may be difficult, however, to pull 4 electrons away from these atoms. Often, instead of giving up these electrons, these elements simply share them with another element. (We will talk about the sharing of electrons later.) But, even in the case of sharing electrons, the valence number of these elements is considered to be (___).
+4	8. Tin, Sn, and lead, Pb, have valence numbers of +4 in some reactions and +2 in others. Both elements have 4 electrons in their outer shell. Two of these electrons are in the first sub-shell and two are in the second sub-shell. In some reactions, tin and lead give up only these two electrons from the second sub-shell. Thus, their valence number in these reactions is (___).
+2	9. The elements in columns VA and VB have *(___) electrons in their outer shell. *how many?
5	10. These five outer electrons are distributed as follows: 2 are in the first sub-shell and 3 are in the second sub-shell. In some chemical reactions, these elements might give up only the 3 electrons of the second sub-shell. In such cases, their valence number would be (___).
+3	11. In other chemical reactions, they might give up all of the electrons in their outer shell. In these reactions, their valence number is (___).

+5

12. And finally, in some reactions they might gain 3 electrons from some other atom. Their second sub-shell would then be completely filled since the second sub-shell can always hold 6 electrons.

Since these atoms would then have 3 more electrons than they have protons, or 3 extra minus (-) charges, their valence number would be (___).

-3

13. As you can see, it is difficult to predict the valence number of the elements in the columns headed by Roman numeral V. Generally, +3 and +5 are the most common.

The elements in columns VIA and VIB have *(___) electrons in the outer shell. *how many?

6

14. Like the elements in columns VA and VB, the valence numbers of the elements in VIA and VIB are difficult to predict.

Oxygen, O, will gain 2 electrons in chemical reactions to completely fill its L shell or 2nd energy level. Thus, its valence number is (___).

-2

15. The elements in columns VIIA and VIIB have *(___) electrons in their outer shell. *how many?

7

16. To completely fill their outer shell (which has two sub-shells), these elements have but to gain one electron. If they gain one electron, their valence number will be (___).

-1

17. The elements in columns VIIIA and VIIIB have *(___) electrons in their outer shell. *how many?

8

18. The elements in column VIIIA are inert. This means that they do not react readily with any other element. The eight outer electrons completely fill the outer shell (which has two sub-shells). Thus, these elements do not gain or lose any electrons in reactions.

The same thing is not true of the elements in column VIIIB. These elements have 18 electrons in the shell next to the outer shell. Sometimes one or more of these electrons skip to the outer shell and then are lost in chemical reactions. Since they lose electrons in these reactions, their valence number is *(___).

*negative or positive

positive

19. For example, iron (Fe) may have a valence number of +2 or +3. The +2 iron ion is called the ferrous or iron II ion; the +3 iron ion is called the ferric or iron III ion.

The iron ion with the lower or smaller valence number has a a name that ends with *(___).

*last 3 letters

ous

20. The elements are arranged in the Periodic Table according to their atomic (___).

number

21. Find aluminum (Al) in the Periodic Table.

It has *(_a_) electron(s) in its outer shell.
Its outer shell is the (_b_) shell or (_c_) energy level.
Its valence number is (_d_). *how many?

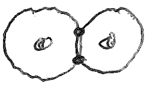
a. 3
b. M
c. 3rd
d. +3

22. Find oxygen (O).

It has *(_a_) electron(s) in its outer shell.
Its outer shell is the (_b_) shell or (_c_) energy level.
Its valence number is (_d_). *how many?

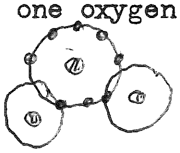
a. 6
b. L
c. 2nd
d. -2

23. Sometime ago, we mentioned that atoms may share electrons. For example, hydrogen (H) has one outer electron. It may share that electron with another hydrogen atom.



The diagram shows 2 hydrogen atoms that are sharing their outer electrons with each other. Note that the two electrons are moving around both nuclei. When the two electrons are orbiting around the nucleus on the left, that atom's K shell is completely filled. (The K shell will hold only 2 electrons.) The same is true when the electrons move around the nucleus to the right. Since the electrons are moving so very rapidly (at about the speed of light) and traveling such a short distance, one might say that the K shells of both atoms are filled all the time.

This diagram shows 2 hydrogen atoms and one oxygen atom sharing outer electrons. Each hydrogen atom now has its one outer electron and one of the oxygen outer electrons filling its K shell. The oxygen atom has its 6 outer electrons and two hydrogen electrons (one from each atom) filling its L shell.



These three atoms have combined to form one molecule of (___).

water (H_2O)

24. Certain groups of atoms stay united during chemical reactions. These groups are called radicals. They act just as though they are single atoms. They also have definite valence numbers.

Name	Symbol	Valence Number
Ammonium	NH_4	+1
Carbonate	CO_3	-2
Hydroxide	OH	-1
Nitrate	NO_3	-1
Sulfate	SO_4	-2

The ammonium radical has a valence number of +1. The nitrate (___) has the symbol, NO_3.

radical

25. The (_a_) radical has the symbol, CO_3. The only radical above with a positive or plus valence number is the (_b_) radical. The symbol for the sulfate radical is (_c_).

a. carbonate
b. ammonium
c. SO_4

26. In writing the formula for a compound, the symbol of the element or radical with a plus valence number is written before the symbol of the element or radical with a negative valence number.

One sodium atom (+1) combines with one chlorine atom (-1) to form a molecule of sodium chloride. The formula for sodium chloride is (__).

NaCl

27. One hydroxide radical, whose symbol is OH and whose valence number is -1, will combine with one potassium ion (symbol, K; valence number, +1) to form one molecule of potassium hydroxide. The formula for potassium hydroxide is (___).

KOH

28. All compounds are electrically neutral. Therefore, the total plus valence must equal the total minus valence. Let us write the formula for aluminum chloride. The valence number of the aluminum ion, Al, is +3; the valence number of the chlorine ion, Cl, is -1.

$$Al^{+3} \quad Cl^{-1}$$
$$AlCl_3$$

The total positive or plus valence of aluminum chloride is +3 (one aluminum ion). The total negative or minus valence of the compound is (___).

-3

29. The 3 in the formula $AlCl_3$ tells you that there are 3 *(___) ions in a molecule of aluminum chloride.
*name

chlorine or chloride

30. The formula for calcium hydroxide is:

$$Ca^{+2} \quad OH^{-1}$$
$$Ca(OH)_2$$

Notice that when you use more than one radical, the symbol for the radical is placed in parentheses and the number is placed outside. As written above, $Ca(OH)_2$, the molecule contains *(_a_) ion(s) of calcium, *(_b_) atom(s) of oxygen, and *(_c_) atoms of hydrogen.
*how many?

a. 1
b. 2
c. 2

31. If we had written the formula as $CaOH_2$ (without the parentheses), this would indicate that the molecule contains 1 calcium ion, *(_a_) oxygen atom(s), and *(_b_) hydrogen atom(s).
*how many?

a. 1
b. 2

32. Notice also that in naming compounds made up of two elements, or two radicals, or one element and one radical, that the name of the element or radical having the minus valence number is changed to end in "ide".

The name of NaCl is sodium chlor<u>ide</u>.
The name of $Ca(OH)_2$ is calcium hydrox<u>ide</u>.
The name of MgO is (___).

magnesium oxide

33. In writing the formula for a compound, the symbol of the element or radical having a (___) valence number is written first.

positive or plus	34.	Molecules are constantly in motion. Because of this motion two substances may mix. The molecules of the two substances move around each other; they intermingle. The mixing of substances because of molecular motion is called <u>diffusion</u>. Gases will pass through porous solids due to the mixing of the gas and solid molecules. The process is called (___).
diffusion	35.	Molecules move because they possess energy. When you heat a substance, its molecules take on or absorb more energy. Therefore, the molecules will move *(___). *faster or slower
faster	36.	The kinetic energy (energy of motion) of molecules, thus, depends upon the (___) of the molecules.
temperature	37.	According to the <u>kinetic theory of matter</u>, the molecules of a solid vibrate about fixed positions; the molecules of a liquid slide over one another freely, and the molecules of a (___) are widely separated and move most rapidly.
gas		

Student's Name________________________ School______________ Sec. No.______

PART 12

1. ____________________

2a. ____________________

2b. ____________________

2c. ____________________

3. ____________________

4. ____________________

5. ____________________

6. ____________________

7. ____________________

8. ____________________

9. ____________________

10. ____________________

11. ____________________

12. ____________________

13. ____________________

14. ____________________

15. ____________________

16. ____________________

17. ____________________

18. ____________________

19. ____________________

20. ____________________

21a. ____________________

21b. ____________________

21c. ____________________

21d. ____________________

22a. ____________________

22b. ____________________

22c. ____________________

22d. ____________________

23. ____________________

24. ____________________

25a. ____________________

25b. ____________________

25c. ____________________

26. ____________________

27. ____________________

28. ____________________

29. ____________________

30a. ____________________

30b. ____________________

30c. ____________________

31a. ____________________

31b. ____________________

32. ____________________

33. ____________________

34. ____________________

35. ____________________

36. ____________________

37. ____________________

APPENDIX E

VARIANCES OF THE CRITERION VARIABLES AND THE COVARIATES

Q = ITED Quantitative Standard Score
SR = ITED Science Reading Standard Score
C = ITED Composite Standard Score
IQ = CTMM Intelligence Quotient
PR = Recall Pre-Test Score
PA = Application Pre-Test Score
PT = Total Pre-Test Score
RG = Recall Gain Score
AG = Application Gain Score
TG = Total Gain Score

Variances of the Criterion Variables and the Covariates

		Instructional Method		
		Conventional	Introductory	Review
Teacher A	Q	19.78	19.50	24.15
	SR	17.81	21.73	20.94
	C	18.48	21.73	15.79
	IQ	142.11	102.85	130.31
	PR	7.07	7.16	6.25
	PA	5.77	6.29	7.47
	PT	19.17	21.65	19.26
	RG	18.73	26.75	25.91
	AG	18.71	22.96	29.39
	TG	53.53	79.36	92.97
Teacher B	Q	18.79	28.52	35.60
	SR	29.16	23.28	24.01
	C	19.73	18.22	28.13
	IQ	136.90	126.20	147.56
	PR	6.76	5.53	6.18
	PA	4.68	6.53	12.50
	PT	14.81	19.52	30.93
	RG	27.10	18.95	22.19
	AG	34.04	31.85	35.64
	TG	104.47	87.43	95.57
Teacher C	Q	22.40	57.88	25.04
	SR	6.87	33.08	22.82
	C	11.92	45.53	21.44
	IQ	102.19	268.32	176.86
	PR	6.08	12.97	7.47
	PA	5.69	15.22	7.13
	PT	12.61	48.69	22.82
	RG	22.28	22.47	28.81
	AG	37.26	32.63	26.19
	TG	101.12	95.56	90.24
Teacher D	Q	20.79	29.07	37.86
	SR	17.43	26.44	27.83
	C	21.74	19.67	26.99
	IQ	167.65	151.19	218.79
	PR	6.73	10.73	9.65
	PA	5.49	11.56	9.91
	PT	16.55	32.99	35.63
	RG	12.03	31.66	17.29
	AG	17.51	33.17	25.45
	TG	39.68	105.15	69.45
Teacher E	Q	30.92	21.69	27.72
	SR	29.74	25.05	24.65
	C	27.58	17.43	18.42
	IQ	91.54	182.13	172.16
	PR	13.92	5.25	13.09
	PA	14.02	7.48	20.37
	PT	41.32	15.30	57.42
	RG	17.54	22.90	17.96
	AG	24.03	13.53	20.94
	TG	62.46	50.33	57.72

APPENDIX F

STANDARDIZED TEST SCORES, PRE-TEST SCORES, POST-TEST SCORES, AND GAIN SCORES FOR THE INDIVIDUAL STUDENTS

Q = ITED Quantitative Standard Score
SR = ITED Science Reading Standard Score
C = ITED Composite Standard Score
IQ = CTMM Intelligence Quotient
R1 = Recall Pre-Test Score
A1 = Application Pre-Test Score
T1 = Total Pre-Test Score
R2 = Recall Post-Test Score
A2 = Application Post-Test Score
T2 = Total Post-Test Score
RG = Recall Gain Score
AG = Application Gain Score
TG = Total Gain Score

SECTION C-1

Conventional

Student No.	Q	SR	C	IQ	R1	A1	T1	R2	A2	T2	RG	AG	TG
1	11	10	12	96	10	4	14	18	13	31	8	9	17
2	9	10	12	106	5	6	11	14	16	30	9	10	19
3	6	12	8	103	2	3	5	13	15	28	11	12	23
4	16	10	11	105	7	2	9	18	17	35	11	15	26
5	8	9	11	94	8	4	12	16	16	32	8	12	20
6	9	7	9	83	7	2	9	15	12	27	8	10	18
7	6	7	8	90	3	4	7	10	4	14	7	0	7
8	11	13	15	94	6	5	11	17	9	26	11	4	15
9	7	12	7	97	5	4	9	6	4	10	1	0	1
10	14	12	11	104	9	1	10	18	14	32	9	13	22
11	7	7	8	103	7	1	8	14	5	19	7	4	11
12	7	9	10	105	10	4	14	12	10	22	2	6	8
13	11	10	15	117	8	5	13	17	17	34	9	12	21
14	16	13	17	109	8	6	14	18	19	37	10	13	23
15	11	12	9	117	5	8	13	8	8	16	3	0	3
16	8	12	11	109	6	10	16	15	9	24	9	-1	8
17	11	11	6	99	4	5	9	6	4	10	2	-1	1
18	22	12	14	111	8	10	18	23	22	45	15	12	27
19	15	8	12	108	12	6	18	15	17	32	3	11	14
20	20	6	14	111	7	8	15	12	14	26	5	6	11
21	9	13	11	117	7	6	13	17	19	36	10	13	23
22	11	4	8	96	7	4	11	15	12	27	8	8	16
23	19	11	10	100	8	6	14	21	24	45	13	18	31
24	9	13	15	121	6	7	13	27	24	51	21	17	38
25	7	13	5	81	3	4	7	4	7	11	1	3	4
26	7	12	10	95	10	4	14	16	7	23	6	3	9
27	20	15	20	111	11	8	19	27	28	55	16	20	36

SECTION C-2

Review

Student No.	Q	SR	C	IQ	R1	A1	T1	R2	A2	T2	RG	AG	TG
28	12	13	11	105	5	6	11	23	16	39	18	10	28
29	20	8	15	112	9	3	12	22	21	43	13	18	31
30	11	12	13	103	10	7	17	18	9	27	8	2	10
31	14	18	18	118	8	6	14	22	11	33	14	5	19
32	16	18	18	122	10	9	19	30	25	55	20	16	36
33	13	13	13	115	10	8	18	21	15	36	11	7	18
34	10	16	19	108	11	4	15	28	22	50	17	18	35
35	13	19	14	129	9	4	13	10	12	22	1	8	9
36	9	8	7	74	5	3	8	10	5	15	5	2	7
37	20	18	23	121	11	10	21	29	27	56	18	17	35
38	10	10	10	117	5	5	10	19	14	33	14	9	23
39	16	10	15	109	9	9	18	23	23	46	14	14	28
40	27	26	27	138	15	8	23	28	27	55	13	19	32
41	9	2	8	104	7	1	8	17	17	34	10	16	26
42	10	12	13	111	4	4	8	13	12	25	9	8	17
43	12	12	13	115	9	10	19	21	22	43	12	12	24
44	14	12	15	117	10	7	17	23	17	40	13	10	23
45	13	10	14	110	10	7	17	25	20	45	15	13	28
46	25	10	11	100	6	4	10	4	8	12	-2	4	2
47	26	23	24	135	17	14	31	26	30	56	9	16	25
48	6	11	8	95	6	6	12	9	9	18	3	3	6
49	22	18	18	116	8	4	12	13	11	24	5	7	12
50	16	7	12	113	8	7	15	21	15	36	13	8	21
51	14	10	11	93	13	6	19	16	15	31	3	9	12

SECTION C-3

Review

Student No.	Q	SR	C	IQ	R1	A1	T1	R2	A2	T2	RG	AG	TG
52	15	25	23	126	9	7	16	25	22	47	16	15	31
53	7	10	11	84	4	4	8	9	6	15	5	2	7
54	8	10	8	99	6	6	12	12	12	24	6	6	12
55	12	8	10	114	11	7	18	18	22	40	7	15	22
56	10	11	16	115	10	10	20	23	18	41	13	8	21
57	10	11	7	85	7	1	8	14	7	21	7	6	13
58	14	18	17	120	8	5	13	26	25	51	18	20	38
59	12	15	16	98	10	4	14	19	20	39	9	16	25
60	13	10	9	89	9	7	16	18	22	40	9	15	24
61	13	8	16	105	7	5	12	22	20	42	15	15	30
62	23	18	22	120	8	7	15	26	22	48	18	15	33
63	21	13	16	118	12	5	17	26	19	45	14	14	28
64	15	9	10	96	4	5	9	11	13	24	7	8	15
65	18	11	14	109	10	4	14	24	20	44	14	16	30
66	13	10	12	98	10	8	18	23	16	39	13	8	21
67	12	14	13	100	6	0	6	26	18	44	20	18	38
68	16	14	14	105	9	2	11	21	13	34	12	11	23
69	15	16	19	113	12	6	18	25	22	47	13	16	29
70	21	15	17	116	9	5	14	20	22	42	11	17	28
71	15	12	16	132	8	6	14	30	22	52	22	16	38
72	8	8	11	102	6	2	8	25	17	42	19	15	34

SECTION C-4

Introduction

Student No.	Q	SR	C	IQ	R1	A1	T1	R2	A2	T2	RG	AG	TG
73	7	10	9	99	4	6	10	10	6	16	6	0	6
74	19	13	13	109	8	5	13	14	13	27	6	8	14
75	9	12	12	97	5	4	9	6	9	15	1	5	6
76	18	14	18	114	11	9	20	23	21	44	12	12	24
77	11	14	14	100	5	3	8	19	18	37	14	15	29
78	16	21	19	107	8	7	15	25	26	51	17	19	36
79	10	15	11	100	6	4	10	17	11	28	11	7	18
80	12	17	18	116	11	5	16	23	20	43	12	15	27
81	9	5	11	106	7	4	11	16	7	23	9	3	12
82	6	10	10	99	9	8	17	21	19	40	12	11	23
83	9	6	7	108	6	5	11	20	17	37	14	12	26
84	7	11	10	86	3	5	8	12	12	24	9	7	16
85	1	11	7	77	7	7	14	8	4	12	1	-3	-2
86	7	10	8	101	5	4	9	10	15	25	5	11	16
87	10	10	8	97	6	4	10	13	18	31	7	14	21
88	9	7	7	97	7	5	12	13	7	20	6	2	8
89	10	11	9	80	5	4	9	22	18	40	17	14	31
90	23	18	20	128	7	7	14	25	25	50	18	18	36
91	11	12	9	97	3	4	7	13	8	21	10	4	14
92	9	13	7	95	5	4	9	14	14	28	9	10	19
93	8	11	12	101	10	5	15	20	13	33	10	8	18
94	15	10	13	118	7	4	11	24	13	37	17	9	26
95	18	12	15	101	8	7	15	25	25	50	17	18	35

SECTION C-5

Introduction

Student No.	Q	SR	C	IQ	R1	A1	T1	R2	A2	T2	RG	AG	TG
96	28	28	31	132	13	11	24	29	28	57	16	17	33
97	23	17	21	111	7	10	17	30	26	56	23	16	39
98	21	16	19	129	6	7	13	26	25	51	20	18	38
99	19	21	25	126	11	9	20	29	26	55	18	17	35
100	21	17	21	138	9	7	16	26	18	44	17	11	28
101	22	23	24	131	11	8	19	28	25	53	17	17	34
102	18	17	18	125	12	6	18	29	28	57	17	22	39
103	22	23	27	138	19	12	31	28	26	54	9	14	23
104	25	22	25	132	14	9	23	30	27	57	16	18	34
105	25	19	19	124	9	6	15	29	25	54	20	19	39
106	25	25	28	105	12	7	19	28	25	53	16	18	34
107	26	19	22	116	12	15	27	24	26	50	12	11	23
108	14	15	18	129	11	7	18	24	22	46	13	15	28
109	16	13	21	111	8	5	13	17	17	34	9	12	21
110	24	14	18	121	15	12	27	29	27	56	14	15	29
111	23	15	20	125	11	5	16	25	24	49	14	19	33
112	28	12	18	121	12	9	21	26	28	54	14	19	33
113	23	26	28	120	15	14	29	29	27	56	14	13	27
114	33	19	26	153	10	11	21	28	29	57	18	18	36
115	21	22	23	120	11	10	21	25	23	48	14	13	27
116	22	24	23	139	12	13	25	27	24	51	15	11	26
117	29	18	23	138	9	12	21	28	28	56	19	16	35
118	25	20	20	132	10	13	23	26	22	48	16	9	25
119	25	19	23	120	7	3	10	27	26	53	20	23	43
120	20	22	23	129	14	9	23	28	28	56	14	19	33
121	26	27	26	112	13	9	22	29	29	58	16	20	36
122	21	23	20	126	15	14	29	27	28	55	12	14	26
123	31	27	31	133	17	24	41	30	30	60	13	6	19
124	24	10	19	119	12	7	19	27	25	52	15	18	33

SECTION A-1

Introduction

Student No.	Q	SR	C	IQ	R1	A1	T1	R2	A2	T2	RG	AG	TG
125	11	10	12	109	8	6	14	16	16	32	8	10	18
126	3	12	8	94	10	3	13	9	10	19	-1	7	6
127	24	25	25	120	13	12	25	29	30	59	16	18	34
128	8	10	10	102	4	3	7	21	14	35	17	11	28
129	16	13	15	110	9	8	17	24	16	40	15	8	23
130	6	8	9	99	6	4	10	7	5	12	1	1	2
131	9	10	10	116	8	3	11	9	13	22	1	10	11
132	12	17	19	111	11	7	18	24	23	47	13	16	29
133	12	16	17	109	8	10	18	22	19	41	14	9	23
134	14	11	14	98	7	5	12	16	16	32	9	11	20
135	9	5	6	92	4	6	10	11	12	23	7	6	13
136	10	8	7	88	3	5	8	7	3	10	4	-2	2
137	16	8	14	115	7	6	13	22	16	38	15	10	25
138	11	12	13	101	3	1	4	10	13	23	7	12	19
139	10	2	8	94	5	5	10	12	10	22	7	5	12
140	8	12	7	93	8	7	15	13	12	25	5	5	10
141	13	9	8	80	4	5	9	10	8	18	6	3	9
142	13	8	15	108	8	4	12	17	17	34	9	13	22
143	8	12	9	106	7	7	14	17	14	31	10	7	17
144	12	8	10	97	10	8	18	14	11	25	4	3	7
145	6	12	13	108	8	6	14	17	15	32	9	9	18

SECTION A-2

Conventional

Student No.	Q	SR	C	IQ	R1	A1	T1	R2	A2	T2	RG	AG	TG
146	12	18	20	110	13	11	24	26	23	49	13	12	25
147	10	12	13	96	6	7	13	20	19	39	14	12	26
148	21	15	19	114	12	6	18	23	24	47	11	18	29
149	16	10	14	102	6	7	13	23	12	35	17	5	22
150	16	8	12	119	8	6	14	16	21	37	8	15	23
151	16	16	17	130	13	5	18	27	26	53	14	21	35
152	10	8	12	108	7	8	15	21	19	40	14	11	25
153	7	8	8	90	5	4	9	6	12	18	1	8	9
154	9	11	9	91	9	3	12	12	16	28	3	13	16
155	13	10	13	118	10	7	17	23	21	44	13	14	27
156	21	19	24	121	15	9	24	26	23	49	11	14	25
157	6	6	8	94	9	4	13	23	19	42	14	15	29
158	10	10	6	88	8	7	15	14	10	24	6	3	9
159	13	22	17	125	15	11	26	25	24	49	10	13	23
160	11	8	17	123	10	7	17	19	23	42	9	16	25
161	11	11	11	96	9	3	12	10	16	26	1	13	14
162	18	19	21	126	15	12	27	24	26	50	9	14	23
163	15	13	18	110	10	3	13	23	19	42	13	16	29
164	7	10	10	109	9	3	12	14	17	31	5	14	19
165	10	8	7	105	8	4	12	16	8	24	8	4	12
166	8	13	10	106	6	8	14	14	10	24	8	2	10
167	11	16	17	117	9	7	16	25	25	50	16	18	34
168	19	15	18	107	12	7	19	21	24	45	9	17	26
169	6	9	10	89	6	4	10	8	10	18	2	6	8
170	19	10	13	119	14	8	22	21	20	41	7	12	19
171	7	10	6	73	4	6	10	13	14	27	9	8	17

SECTION A-3

Conventional

Student No.	Q	SR	C	IQ	R1	A1	T1	R2	A2	T2	RG	AG	TG
172	13	19	20	125	6	6	12	21	17	38	15	11	26
173	11	15	15	116	11	7	18	27	20	47	16	13	29
174	13	15	15	110	6	6	12	16	16	32	10	10	20
175	11	13	15	109	9	4	13	18	19	37	9	15	24
176	16	11	11	120	8	10	18	12	14	26	4	4	8
177	10	11	9	110	8	1	9	16	13	29	8	12	20
178	23	19	21	119	9	5	14	27	26	53	18	11	29
179	15	16	16	101	9	5	14	26	19	45	17	14	31
180	14	12	13	105	5	3	8	12	18	30	7	15	22
181	13	12	15	115	9	6	15	20	19	39	11	13	24
182	20	17	15	112	8	4	12	20	17	37	12	13	25
183	7	1	7	96	6	5	11	15	14	29	9	9	18
184	15	19	17	119	7	6	13	20	16	36	13	10	23
185	12	13	15	110	10	10	20	22	23	45	12	13	25
186	15	10	13	110	6	6	12	17	16	33	11	10	21
187	20	13	14	98	9	2	11	24	22	46	15	20	35
188	9	5	9	97	6	5	11	13	12	25	7	7	14
189	8	12	8	100	7	2	9	11	9	20	4	7	11
190	16	14	16	127	10	8	18	22	21	43	12	13	25
191	10	8	6	99	8	6	14	8	10	18	0	4	4
192	15	7	12	115	6	3	9	17	19	36	11	16	27
193	20	7	13	115	8	6	14	13	12	25	5	6	11
194	16	15	19	116	6	4	10	18	20	38	12	16	28
195	21	13	12	100	7	5	12	19	16	35	12	11	23
196	18	7	13	109	10	8	18	20	20	40	10	12	22
197	14	12	13	90	9	5	14	17	19	36	8	14	22

SECTION A-4

Review

Student No.	Q	SR	C	IQ	R1	A1	T1	R2	A2	T2	RG	AG	TG
198	18	10	15	104	5	6	11	15	22	37	10	16	26
199	14	23	20	124	11	13	24	27	21	48	16	8	24
200	13	16	17	120	8	6	14	22	24	46	14	18	32
201	15	13	16	115	8	5	13	14	18	32	6	13	19
202	7	6	7	115	7	8	15	15	12	27	8	4	12
203	10	15	19	111	11	7	18	21	11	32	6	13	19
204	18	13	14	113	10	6	16	14	14	28	4	8	12
205	20	15	18	123	9	15	24	25	25	50	6	10	16
206	21	14	16	119	12	6	18	24	24	48	12	18	30
207	14	13	18	121	8	4	12	22	21	43	14	17	31
208	22	16	17	118	11	8	19	29	25	54	18	17	35
209	14	15	15	133	6	9	15	23	26	49	17	17	34
210	25	19	21	121	11	12	23	26	29	55	15	17	32
211	15	10	11	117	7	4	11	11	7	18	4	3	7
212	20	21	18	127	7	3	10	26	24	50	19	21	40
213	13	17	15	111	5	6	11	20	21	41	15	15	30
214	18	24	23	123	17	9	26	29	30	59	12	21	33
215	24	21	24	128	12	6	18	27	27	54	15	21	36
216	15	15	16	116	6	3	9	22	19	41	16	16	32
217	8	7	8	89	7	4	11	13	15	28	6	11	17
218	13	12	14	122	9	8	17	18	19	37	9	11	20
219	19	15	18	111	7	5	12	19	18	37	12	13	25
220	21	12	14	126	10	6	16	16	14	30	6	8	14
221	22	14	16	120	6	6	12	27	25	52	21	19	40
222	21	12	18	128	10	8	18	27	29	56	17	21	38
223	19	5	14	123	13	8	21	18	17	35	5	9	14
224	14	19	18	125	7	5	12	22	24	46	15	19	34

SECTION A-5

Review

Student No.	Q	SR	C	IQ	R1	A1	T1	R2	A2	T2	RG	AG	TG
225	16	8	14	123	10	6	16	25	23	48	15	17	32
226	10	8	15	109	9	1	10	28	18	46	19	17	36
227	9	8	12	103	7	2	9	18	14	32	11	12	23
228	12	10	11	110	7	6	13	17	13	30	10	7	17
229	9	10	8	99	4	4	8	17	15	32	13	11	24
230	18	12	15	106	10	7	17	24	27	51	14	20	34
231	10	11	15	122	6	3	9	17	22	39	11	19	30
232	20	16	16	121	7	3	10	26	19	45	19	16	35
233	10	6	7	99	9	2	11	14	9	23	5	7	12
234	14	12	10	95	6	1	7	15	13	28	9	12	21
235	7	7	10	93	7	3	10	10	14	24	3	11	14
236	15	13	16	104	13	7	20	19	17	36	6	10	16
237	18	10	14	123	10	6	16	14	20	34	4	14	18
238	7	9	12	100	7	7	14	18	13	31	11	6	17
239	12	9	14	102	6	5	11	7	8	15	1	3	4
240	9	12	15	110	7	5	12	14	16	30	7	11	18
241	15	15	16	107	10	6	16	24	22	46	14	16	30
242	22	13	17	110	11	5	16	23	22	45	12	17	29
243	19	6	11	108	7	5	12	20	14	34	13	9	22
244	15	5	9	115	8	3	11	16	17	33	8	14	22
245	6	8	6	86	4	5	9	5	5	10	1	0	1
246	14	15	15	118	8	5	13	14	11	25	6	6	12
247	6	8	8	84	8	2	10	12	19	31	4	17	21
248	14	18	16	124	8	8	16	23	21	44	15	13	28
249	13	8	10	102	11	4	15	18	10	28	7	6	13

SECTION E-1

Conventional

Student No.	Q	SR	C	IQ	R1	A1	T1	R2	A2	T2	RG	AG	TG
251	22	23	20	115	8	10	18	30	27	57	22	17	39
252	23	27	28	108	9	11	20	29	26	55	20	15	35
253	26	26	23	125	12	5	17	26	25	51	14	20	34
254	16	14	16	118	7	7	14	23	18	41	16	11	27
255	24	24	25	136	10	7	17	27	26	53	17	19	36
256	11	10	11	111	4	5	9	11	5	16	7	0	7
257	19	24	23	128	14	16	30	22	18	40	8	2	10
258	18	21	21	108	14	6	20	30	26	56	16	20	36
259	21	21	26	123	21	8	29	30	27	57	9	19	28
260	21	25	27	132	11	8	19	29	24	53	18	16	34
261	12	12	12	104	5	3	8	19	12	31	14	9	23
262	31	24	27	126	12	11	23	30	26	56	18	15	33
263	21	22	23	128	13	14	27	27	26	53	14	12	26
264	18	22	19	106	8	3	11	22	18	40	14	15	29
265	21	18	20	116	14	14	28	30	24	54	16	10	26
266	15	14	14	121	7	10	17	28	22	50	21	12	33
267	14	23	19	104	8	10	18	26	23	49	18	13	31
268	14	10	15	114	8	6	14	24	20	44	16	14	30
269	25	20	23	135	14	12	26	24	25	49	10	13	23
270	21	15	18	124	9	8	17	25	21	46	16	13	29
271	27	16	21	129	10	11	21	22	19	41	12	8	20
272	13	15	12	112	8	9	17	13	20	33	5	11	16
273	18	19	17	120	10	7	17	22	16	38	12	9	21
274	27	26	28	123	11	11	22	30	30	60	19	19	38
275	18	23	20	124	14	12	26	28	27	55	14	15	29
276	18	9	13	105	5	6	11	14	14	28	9	8	17
277	19	20	19	116	7	8	15	21	20	41	14	12	26
278	35	26	29	124	16	17	33	29	29	58	13	12	25
279	20	13	16	132	9	16	25	25	23	48	16	7	23

SECTION E-2

Review

Student No.	Q	SR	C	IQ	R1	A1	T1	R2	A2	T2	RG	AG	TG
280	22	18	21	121	12	12	24	30	27	57	18	15	33
281	23	25	26	131	23	27	50	28	30	58	5	3	8
282	9	3	8	79	6	7	13	10	5	15	4	-2	2
283	13	15	15	103	3	5	8	25	19	44	22	14	36
284	15	19	19	122	9	9	18	26	24	50	17	15	32
285	20	20	19	131	8	8	16	20	23	43	12	15	27
286	16	14	15	110	7	10	17	23	17	40	16	7	23
287	19	16	18	121	8	10	18	29	26	55	21	16	37
288	19	15	15	95	8	7	15	17	16	33	9	9	18
289	7	9	10	100	9	5	14	13	9	22	4	4	8
290	14	19	17	112	10	9	19	24	20	44	14	11	25
291	10	12	12	97	8	5	13	27	14	41	19	9	28
292	9	12	13	117	7	9	16	22	21	43	15	12	27
293	18	15	17	111	8	3	11	23	18	41	15	15	30
294	26	25	22	122	14	13	27	27	28	55	13	15	28
295	22	25	23	130	13	7	20	27	26	53	14	19	33
296	16	17	18	116	13	12	25	29	25	54	16	13	29
297	27	20	21	157	9	11	20	25	23	48	16	12	28
298	23	16	17	125	11	8	19	23	22	45	12	14	26
299	27	27	28	127	16	16	32	28	28	56	12	12	24
300	13	9	11	92	11	4	15	16	15	31	5	11	16
301	24	26	28	128	16	9	25	29	29	58	13	20	33
302	18	24	21	112	14	11	25	28	28	56	14	17	31
303	29	24	25	138	13	21	34	29	28	57	16	7	23
304	23	19	18	104	9	6	15	27	25	52	18	19	37
305	19	25	24	114	15	14	29	26	24	50	11	10	21

SECTION E-3

Introduction

Student No.	Q	SR	C	IQ	R1	A1	T1	R2	A2	T2	RG	AG	TG
306	11	19	16	99	8	8	16	20	17	37	12	9	21
307	13	19	21	119	12	8	20	28	23	51	16	15	31
308	12	15	16	117	9	6	15	25	20	45	16	14	30
309	12	14	12	130	5	10	15	16	11	27	11	1	12
310	19	21	22	132	7	7	14	27	22	49	20	15	35
311	19	12	14	106	7	5	12	24	14	38	17	9	26
312	7	4	7	92	8	5	13	15	13	28	7	8	15
313	8	15	12	96	8	5	13	14	12	26	6	7	13
314	16	23	21	128	10	12	22	28	26	54	18	14	32
315	19	18	17	110	8	9	17	25	21	46	17	12	29
316	16	14	14	110	9	4	13	20	17	37	11	13	24
317	10	17	14	100	6	7	13	20	14	34	14	7	21
318	15	17	15	114	8	8	16	24	16	40	16	8	24
319	26	21	21	121	12	8	20	23	20	43	11	12	23
320	15	8	8	83	6	3	9	11	12	23	5	9	14
321	18	9	12	115	9	5	14	19	13	32	10	8	18
322	11	10	12	94	3	4	7	14	12	26	11	8	19
323	11	9	13	104	6	2	8	10	12	22	4	10	14
324	18	18	17	114	6	12	18	22	16	38	16	4	20
325	10	17	12	123	11	6	17	17	13	30	6	7	13

SECTION E-4

Review

Student No.	Q	SR	C	IQ	R1	A1	T1	R2	A2	T2	RG	AG	TG
326	10	18	17	118	9	9	18	25	22	47	16	13	29
327	14	14	13	107	5	5	10	21	13	34	16	8	24
328	16	13	16	106	7	7	14	21	20	41	14	13	27
329	10	16	15	123	6	6	12	15	16	31	9	10	19
330	14	16	14	115	6	5	11	21	18	39	15	13	28
331	16	12	14	105	8	1	9	24	14	38	16	13	29
332	14	15	13	112	7	4	11	22	12	34	15	8	23
333	13	14	16	110	10	7	17	28	27	55	18	20	38
334	18	13	17	112	8	11	19	16	18	34	8	7	15
335	18	18	16	112	11	5	16	21	18	39	10	13	23
336	19	10	13	108	3	4	7	16	11	27	13	7	20
337	19	9	14	114	7	7	14	20	13	33	13	6	19
338	15	16	17	114	5	5	10	23	18	41	8	13	21
339	16	16	15	115	6	7	13	19	15	34	13	8	21
340	9	9	11	107	7	6	13	21	20	41	14	14	28
341	13	18	14	117	7	7	14	22	21	43	15	14	29
342	12	16	17	122	9	8	17	21	23	44	12	15	27
343	10	18	18	143	13	14	27	24	19	43	11	15	26
344	22	17	20	116	9	8	17	18	14	32	9	6	15
345	13	16	17	107	8	9	17	16	12	28	8	3	11
346	10	15	15	127	7	4	11	16	19	35	9	15	24
347	19	14	17	128	8	3	11	19	19	38	11	16	27
348	16	18	18	117	9	11	20	20	21	41	11	10	21
349	19	17	18	101	6	11	17	28	22	50	22	11	33

SECTION D-1

Conventional

Student No.	Q	SR	C	IQ	R1	A1	T1	R2	A2	T2	RG	AG	TG
401	13	13	11	107	8	5	13	15	19	34	7	14	21
402	16	16	14	135	7	6	13	9	14	23	2	8	10
403	9	15	12	88	2	6	8	13	11	24	11	5	16
404	12	8	10	106	10	7	17	13	15	28	3	8	11
405	7	15	11	105	6	1	7	9	12	21	3	11	14
406	8	3	2	101	6	2	8	6	8	14	0	6	6
407	14	18	11	123	4	3	7	13	12	25	9	9	18
408	12	19	13	116	6	5	11	11	12	23	5	7	12
409	12	18	17	125	5	7	12	12	13	25	7	6	13
410	18	16	15	107	12	8	20	16	25	41	4	17	21
411	18	17	17	114	12	10	22	21	17	38	9	7	16
412	16	18	18	120	12	9	21	18	25	43	6	16	22
413	20	17	17	117	7	10	17	20	18	38	13	8	21
414	19	16	18	126	9	8	17	20	18	38	11	10	21
415	21	13	14	124	8	4	12	16	20	36	8	16	24

SECTION D-2

Review

Student No.	Q	SR	C	IQ	R1	A1	T1	R2	A2	T2	RG	AG	TG
416	18	20	19	133	9	8	17	23	18	41	14	10	24
417	13	12	10	119	2	2	4	9	13	22	7	11	18
418	11	17	17	114	7	4	11	22	22	44	15	18	33
419	15	16	16	129	8	4	12	14	12	26	6	8	14
420	10	11	12	114	3	2	5	12	12	24	9	10	19
421	20	23	21	107	11	8	19	15	18	33	4	10	14
422	20	19	22	131	11	7	18	21	27	48	10	20	30
423	14	15	15	105	6	6	12	22	18	40	16	12	28
424	18	13	15	94	11	7	18	19	23	42	8	16	24
425	4	5	7	83	7	3	10	9	4	13	2	1	3
426	21	20	18	138	10	6	16	20	24	44	10	18	28
427	14	15	14	107	8	5	13	14	8	22	6	3	9
428	23	16	18	135	9	7	16	18	24	42	9	17	26
429	8	11	8	115	12	7	19	17	19	36	5	12	17
430	16	20	16	100	9	5	14	15	15	30	6	10	16
431	27	22	22	121	11	9	20	27	28	55	16	19	35
432	21	28	24	129	13	13	26	26	28	54	13	15	28
433	8	13	11	97	4	3	7	13	12	25	9	9	18
434	23	21	22	103	11	12	23	25	27	52	14	15	29
435	18	20	19	115	4	3	7	16	17	33	12	14	26
436	26	23	26	121	10	11	21	24	28	52	14	17	31

SECTION D-3

Introduction

Student No.	Q	SR	C	IQ	R1	A1	T1	R2	A2	T2	RG	AG	TG
437	6	10	7	93	5	2	7	7	5	12	2	3	5
438	15	10	11	96	7	1	8	8	5	13	1	4	5
439	15	12	12	109	11	2	13	10	5	15	-1	3	2
440	16	19	19	138	7	6	13	16	21	37	9	15	24
441	18	18	16	121	8	9	17	13	17	30	5	8	13
442	11	15	14	117	11	3	14	13	18	31	2	15	17
443	7	13	12	106	9	6	15	9	8	17	0	2	2
444	16	11	11	98	7	7	14	10	9	19	3	2	5
445	11	12	11	105	7	3	10	16	16	32	9	13	22
446	11	9	8	108	4	3	7	11	8	19	7	5	12
447	7	16	15	104	6	8	14	17	15	32	11	7	18
448	22	19	18	112	6	7	13	12	22	34	6	15	21
449	13	13	15	112	8	5	13	14	17	31	6	12	18
450	24	19	19	123	8	11	19	21	27	48	13	16	29
451	10	9	10	94	10	6	16	10	5	15	0	-1	-1
452	12	16	14	102	3	5	8	12	18	30	9	13	22
453	19	13	17	117	9	7	16	18	22	40	9	15	24
454	23	15	19	104	11	7	18	22	19	41	11	12	23
455	16	16	15	124	9	8	17	15	14	29	6	6	12
456	12	18	15	114	7	7	14	9	8	17	2	1	3
457	11	15	14	106	12	1	13	21	23	44	9	22	31
458	13	12	13	97	6	4	10	12	8	20	6	4	10
459	13	9	13	117	6	5	11	16	13	29	10	8	18
460	13	7	11	95	6	5	11	14	22	36	8	17	25
461	14	6	12	101	7	5	12	9	8	17	2	3	5
462	14	13	13	112	8	5	13	9	8	17	1	3	4

SECTION D-4

Conventional

Student No.	Q	SR	C	IQ	R1	A1	T1	R2	A2	T2	RG	AG	TG
463	19	11	15	110	12	7	19	18	17	35	6	10	16
464	10	11	8	95	9	3	12	8	6	14	-1	3	2
465	13	13	14	111	8	7	15	12	13	25	4	6	10
466	15	12	10	105	8	6	14	8	12	20	0	6	6
467	15	12	11	97	10	5	15	12	10	22	2	5	7
468	9	12	16	114	8	4	12	10	15	25	2	11	13
469	18	21	19	131	9	3	12	11	13	24	2	10	12
470	21	16	19	126	13	6	19	20	24	44	7	18	25
471	11	11	9	108	8	4	12	9	9	18	1	5	6
472	13	17	14	102	6	7	13	10	13	23	4	6	10
473	19	16	18	126	9	3	12	9	8	17	0	5	5
474	15	18	19	122	7	8	15	12	15	27	5	7	12
475	7	12	8	103	6	6	12	15	14	29	9	8	17
476	21	25	24	130	13	6	19	22	24	46	9	18	27
477	20	18	17	118	7	5	12	15	15	30	8	10	18
478	9	3	3	89	8	3	11	9	10	19	1	7	8
479	15	10	11	92	6	5	11	12	13	25	6	8	14
480	20	17	19	112	8	5	13	13	19	32	5	14	19
481	7	13	9	91	8	3	11	10	9	19	2	6	8
482	24	18	23	129	12	11	23	22	20	42	10	9	19
483	14	13	12	116	6	2	8	11	16	27	5	14	19
484	20	15	16	107	7	8	15	16	19	35	9	11	20
485	18	17	16	140	14	6	20	22	21	43	8	15	23
486	16	17	17	118	9	3	12	16	20	36	7	17	24
487	20	16	17	125	9	7	16	14	22	36	5	15	20

SECTION D-5

Introductory

Student No.	Q	SR	C	IQ	R1	A1	T1	R2	A2	T2	RG	AG	TG
488	23	21	20	126	6	11	17	20	22	42	14	11	25
489	20	19	20	121	6	10	16	26	24	50	20	14	34
490	21	24	25	136	11	6	17	24	26	50	13	20	33
491	15	25	22	120	8	7	15	25	20	45	17	13	30
492	21	18	17	116	7	4	11	23	26	49	16	22	38
493	19	18	18	113	6	4	10	18	24	42	12	20	32
494	23	24	22	129	8	6	14	23	22	45	15	16	31
495	15	13	17	124	11	4	15	24	20	44	13	16	29
496	24	15	19	143	8	4	12	20	20	40	12	16	28
497	21	17	17	119	7	4	11	24	16	40	17	12	29
498	10	17	19	127	15	8	23	27	20	47	12	12	24
499	24	29	26	126	8	13	21	27	25	52	19	12	31
500	26	18	22	131	10	5	15	23	18	41	13	13	26
501	14	15	15	125	7	6	13	23	18	41	16	12	28
502	14	19	19	112	9	8	17	25	22	47	16	14	30
503	14	17	15	104	13	6	19	18	17	35	5	11	16
504	21	24	23	118	11	13	24	19	13	32	8	0	8
505	21	19	18	117	9	8	17	23	22	45	14	14	28
506	25	24	23	129	14	13	27	28	26	54	14	13	27
507	24	26	23	131	15	13	28	25	30	55	10	17	27
508	20	16	20	115	12	11	23	18	21	39	6	10	16
509	16	10	15	101	11	7	18	26	18	44	15	11	26
510	21	12	16	103	6	10	16	28	23	51	22	13	35
511	29	24	25	135	20	15	35	27	29	56	7	14	21
512	16	18	20	108	17	14	31	28	28	56	11	14	25

SECTION B-1

Introductory

Student No.	Q	SR	C	IQ	R1	A1	T1	R2	A2	T2	RG	AG	TG
601	6	9	6	89	9	5	14	10	10	20	1	5	6
602	14	18	16	121	14	8	22	21	22	43	7	14	21
603	10	13	10	98	7	8	15	8	13	21	1	5	6
604	8	11	10	87	9	5	14	11	10	21	2	5	7
605	13	24	17	107	8	6	14	26	23	49	18	17	35
606	11	3	8	89	6	5	11	17	5	22	11	0	11
607	20	14	13	113	11	4	15	20	17	37	9	13	22
608	14	13	13	121	8	4	12	19	16	35	11	12	23
609	12	11	12	101	7	6	13	16	10	26	9	4	13
610	14	12	13	101	6	5	11	17	14	31	11	9	20
611	11	14	13	109	9	5	14	16	10	26	7	5	12
612	14	16	12	106	6	5	11	18	22	40	12	17	29
613	13	13	12	107	8	5	13	15	21	36	7	16	23
614	4	3	4	95	4	4	8	8	10	18	4	6	10
615	7	12	13	103	9	6	15	12	6	18	3	0	3
616	11	10	10	81	9	6	15	11	7	18	2	1	3
617	9	10	8	109	7	4	11	13	9	22	6	5	11
618	21	15	13	96	8	8	16	17	19	36	9	11	20
619	19	11	12	106	8	5	13	15	21	36	7	16	23
620	6	12	5	107	5	0	5	12	14	26	7	14	21

SECTION B-2

Introductory

Student No.	Q	SR	C	IQ	R1	A1	T1	R2	A2	T2	RG	AG	TG
621	4	15	11	94	10	6	16	23	14	37	13	8	21
622	6	13	7	101	6	9	15	11	10	21	5	1	6
623	7	9	7	88	6	2	8	10	7	17	4	5	9
624	19	19	21	130	8	4	12	24	24	48	16	20	36
625	18	20	17	104	12	9	21	28	27	55	16	18	34
626	10	10	14	112	9	4	13	22	13	35	13	9	22
627	10	10	15	120	11	5	16	18	16	34	7	11	18
628	11	16	14	102	8	6	14	13	17	30	5	11	16
629	22	15	16	117	8	9	17	24	21	45	16	12	28
630	10	9	8	101	6	4	10	12	13	25	6	9	15
631	21	19	21	120	14	15	29	23	23	46	9	8	17
632	12	9	11	114	5	4	9	16	14	30	11	10	21
633	21	24	20	111	9	7	16	20	22	42	11	15	26
634	22	21	21	114	14	11	25	27	23	50	13	12	25
635	18	17	16	125	8	7	15	19	20	39	11	13	24
636	14	12	16	107	9	4	13	19	12	31	10	8	18
637	10	7	12	95	5	1	6	13	10	23	8	9	17
638	20	9	11	113	8	6	14	20	15	35	12	9	21
639	11	7	10	104	7	6	13	10	5	15	3	-1	2
640	21	14	19	124	8	8	16	25	27	52	17	19	36
641	19	10	9	109	7	4	11	10	8	18	3	4	7
642	19	21	16	120	11	6	17	25	26	51	14	20	34

SECTION B-4

Review

Student No.	Q	SR	C	IQ	R1	A1	T1	R2	A2	T2	RG	AG	TG
671	11	9	6	85	5	7	12	11	13	24	6	6	12
672	23	22	19	125	7	4	11	21	23	44	14	19	33
673	16	18	15	117	6	4	10	17	14	31	11	10	21
674	15	18	16	117	9	7	16	21	19	40	12	12	24
675	19	16	17	102	6	5	11	23	22	45	17	17	34
676	7	10	9	101	3	4	7	9	10	19	6	6	12
677	11	14	13	109	6	7	13	16	24	40	10	17	27
678	10	13	8	102	8	2	10	16	13	29	8	11	19
679	23	22	21	99	9	6	15	25	22	47	16	16	32
680	12	10	13	114	6	2	8	7	6	13	1	4	5
681	9	15	9	101	5	3	8	16	22	38	11	19	30
682	24	23	23	132	13	14	27	28	27	55	15	13	28
683	10	11	6	104	8	5	13	15	9	24	7	4	11
684	21	23	19	123	8	11	19	25	25	50	17	14	31
685	13	11	8	100	3	2	5	10	9	19	7	7	14
686	4	11	11	94	9	7	16	13	11	24	4	4	8
687	15	17	15	112	9	12	21	21	12	33	12	0	12

SECTION B-3

Conventional

Student No.	Q	SR	C	IQ	R1	A1	T1	R2	A2	T2	RG	AG	TG
643	12	6	9	119	6	4	10	17	9	26	11	5	16
644	25	19	21	120	9	8	17	28	28	56	19	20	39
645	12	16	15	123	5	4	9	14	13	27	9	9	18
646	11	13	10	120	6	4	10	8	13	21	2	9	11
647	9	15	12	116	7	4	11	8	11	19	1	7	8
648	14	10	11	101	11	2	13	16	13	29	5	11	16
649	21	23	18	130	4	5	9	22	25	47	18	20	38
650	19	14	16	113	8	6	14	24	21	45	16	15	31
651	12	11	12	107	6	3	9	17	23	40	11	20	31
652	14	18	18	118	10	4	14	28	24	52	18	20	38
653	18	16	17	120	10	4	14	29	25	54	19	21	40
654	9	8	10	110	7	4	11	12	10	22	5	6	11
655	10	12	10	91	6	2	8	12	14	26	6	12	18
656	15	16	19	129	10	5	15	22	21	43	12	16	28
657	21	25	18	99	0	1	1	12	22	34	12	21	33
658	12	8	12	108	8	4	12	17	12	29	9	8	17
659	11	8	11	108	8	7	15	20	22	42	12	15	27
660	16	12	11	116	4	3	7	10	10	20	6	7	13
661	14	14	16	128	10	2	12	21	25	46	11	23	34
662	21	24	22	118	11	6	17	21	20	41	10	14	24
663	13	12	14	126	11	9	20	21	22	43	10	13	23
664	11	5	8	101	8	5	13	12	12	24	4	7	11
665	12	14	12	115	8	2	10	19	22	41	11	20	31
666	13	16	17	90	7	10	17	25	23	48	18	13	31
667	7	6	6	90	4	4	8	11	15	26	7	11	18
668	9	9	5	99	8	5	13	12	7	19	4	2	6
669	12	6	8	121	5	7	12	11	18	29	6	11	17
670	15	12	12	118	9	6	15	19	15	34	10	9	19

BIBLIOGRAPHY

BIBLIOGRAPHY

Books

A Guide to Programed Instructional Materials. New York: The Center for Programed Instruction, Inc., 1962.

Austwick, K. (ed.). Teaching Machines and Programming. New York: The Macmillan Company, 1964.

Brethower, Dale M. Programed Instruction: A Manual of Programing Techniques. Chicago: Educational Methods, Inc., 1963.

Carpenter, C. R., Greenhill, L. P., and others. Comparative Research on Methods and Media for Presenting Programed Courses in Mathematics and English. University Park, Pa.: University Division of Instructional Services, The Pennsylvania State University, 1963.

Coulson, John E. (ed.). Programmed Learning and Computer=Based Instruction. New York: John Wiley and Sons, Inc., 1962.

Cram, David. Explaining "Teaching Machines" and Programming. San Francisco: Fearon Publishers, 1961.

DeCecco, John P. (ed.). Educational Technology. New York: Holt, Rinehart and Winston, 1964.

deGrazia, Alfred and Soh, David A. (eds.). Programs, Teachers, and Machines. New York: Bantam Books, 1964.

Dissertation Abstracts. Ann Arbor: University Microfilms, Inc., 1963, 1964, 1965.

Faltz, Charles I. The World of Teaching Machines. Washington: Electronic Teaching Laboratories, 1961.

Ferguson, George A. Statistical Analysis in Psychology and Education. New York: McGraw-Hill Book Company, Inc., 1959.

Finn, James D. and Perrin, Donald C. Teaching Machines and Programmed Learning. Washington: U.S. Department of Health, Education, and Welfare, 1962.

Fry, Edward B. Teaching Machines and Programmed Instruction. New York: McGraw-Hill Book Company, Inc., 1963.

Gage, N. L. (ed.). Handbook of Research on Teaching. Chicago: Rand McNally and Company, 1963.

Garrett, Henry E. Statistics in Psychology and Education. New York: David McKay Company, Inc., 1958.

Green, Edward J. The Learning Process and Programmed Instruction. New York: Holt, Rinehart and Winston, Inc., 1962.

Hughes, J. L. (ed.). Programed Learning: A Critical Evaluation. Chicago: Educational Methods, Inc., 1963.

Hughes, J. L. Programed Instruction for Schools and Industry. Chicago: Science Research Associates, Inc., 1962.

Kerlinger, Fred N. Foundations of Behavioral Research. New York: Holt, Rinehart and Winston, Inc., 1965.

Lindquist, E. F. Design and Analysis of Experiments in Psychology and Education. Boston: Houghton Mifflin Company, 1953.

Lumsdaine, A. A. and Glaser, Robert (ed.). Teaching Machines and Programmed Learning. Washington: National Education Association, 1960.

Lysaught, Jerome P. and Williams, Clarence M. A Guide to Programmed Instruction. New York: John Wiley and Sons, Inc., 1963.

Mager, Robert F. Preparing Objectives for Programmed Instruction. San Francisco: Fearon Publishers, 1962.

Margulies, Stuart and Eigen, Lewis D. (ed.). Applied Programed Instruction. New York: John Wiley and Sons, Inc., 1962

Markle, Susan Meyer. Good Frames and Bad: A Grammar of Frame Writing. New York: John Wiley and Sons, Inc., 1964.

Ofiesh, Gabriel D. and Meierhenry, Wesley C. Trends in Programmed Instruction. Washington: Department of Audiovisual Instruction, 1964.

Provus, Malcolm and Stone, Douglas E. Programed Instruction in the Classroom. Chicago: Curriculum Advisory Service, Inc., 1963.

Schramm, Wilbur. The Research on Programed Instruction. Washington: U.S. Department of Health, Education, and Welfare, 1964.

________. Programed Instruction: Today and Tomorrow. New York: The Fund for the Advancement of Education, 1962.

Smith, Wendell I. and Moore, J. William (ed.). Programed Learning: Theory and Research. New York: D. Van Nostrand Company, Inc., 1962.

Walker, Helen M. and Lev, Joseph. Statistical Inference. New York: Holt, Rinehart and Winston, 1953.

Winer, B. J. Statistical Principles in Experimental Design. New York: McGraw-Hill Book Company, 1962.

Articles and Periodicals

Alter, Millicent and Silverman, Robert. "The Response in Programed Instruction," Journal of Programed Instruction, 1, 1962, 55-78.

Angell, G. W. "The Effect of Immediate Knowledge of Quiz Results and Final Examination Scores in Freshman Chemistry," Journal of Educational Research, 42, (1949), 391-394.

Barcus, Delbert, Hayman, John L., and Johnson, James T. "Programing Instruction in Elementary Spanish," Phi Delta Kappan, 44, 1963, 269-272.

Cook, Desmond L. "Teaching Machine Terms: A Glossary," Audiovisual Instruction, 6, 1961, 152-153.

Coulson, John, Estavan, Donald P., Melaragno, Ralph J., and Silberman, Harry F. "Effects of Branching in a Computer Controlled Auto-instructional Device," Journal of Applied Psychology, 46, 6 (1962), 389-392.

Coulson, John E. and Silberman, Harry F. "Effects of Three Variables in a Teaching Machine," Journal of Educational Psychology, 51 (1960), 135-143.

Eigen, Lewis D. "High School Student Reaction to Programed Instruction," Phi Delta Kappan, 44, 6 (1963), 282-285.

Finn, James D. "A New Theory for Instructional Technology," Audio Visual Communication Review, 8, 1960, 84-94.

________. "Teaching Machines: Auto-Instructional Devices for the Teacher," NEA Journal, 49 (November, 1960), 41-44.

Fry, Edward B. "Teaching Machine Dichotomy: Skinner vs. Pressey," Psychological Reports, 6, 1960, 11-14.

________. "Teaching Machines: The Coming Automation," Phi Delta Kappan, 41, 1 (1959), 28-31.

Fusco, Gene C. "Programed Self-Instruction: Possibilities and Limitations," The High School Journal, 59, 1960, 85-90.

Gagne, Robert M. and Brown, Larry T. "Some Factors in the Programing of Conceptual Learning," Journal of Experimental Psychology, 62 (1961), 313-321.

Goldbeck, Robert A. and Campbell, Vincent N. "The Effects of Response Mode and Response Difficulty on Programed Learning," Journal of Educational Psychology, 53 (1962), 110-118.

Hough, John B. "An Analysis of the Efficiency and Effectiveness of Selected Aspects of Machine Instruction," Journal of Educational Research, 55 (1962), 467-471.

________. "Research Vindication for Teaching Machines," Phi Delta Kappan, 42 (1962), 240-242.

Hough, John B. and Revsin, Bernard. "Programed Instruction at the College Level: A Study of Several Factors Influencing Learning," Phi Delta Kappan, 44 (1963), 286-291.

Hughes, John L. "Effect of Changes in Programed Text Format and Reduction of Classroom Time on the Achievement and Attitude of Industrial Trainees," Journal of Programed Instruction, 1, 1962, 43-54.

Hughes, John L. and McNamara, W. J. "A Comparative Study of Programmed and Conventional Instruction in Industry," Journal of Applied Psychology, 45 (1961), 225-231.

Kaess, Walter and Zeaman, David. "Positive and Negative Knowledge of Results on a Pressey-type Punchboard," Journal of Experimental Psychology, 60 (1960), 12-17.

Klaus, David J. "The Art of Auto-Instructional Programming," Audio Visual Communication Review, 9, 1961, 130-142.

Krumboltz, John D. and Weisman, Ronald G. "The Effect of Intermittent Confirmation in Programed Instruction," Journal of Educational Psychology, 53, 6 (1962), 250-253.

________. "The effect of Overt vs. Covert Responding to Programed Instruction on Immediate and Delayed Retention," Journal of Educational Psychology, 53, 2 (1962), 89-92.

Krumboltz, John D. and Bonawitz, Barbara. "The Effect of Receiving the Confirming Response in Context in Programed Material," Journal of Educational Research, 55 (1962), 472-475.

Lambert, Philip, Miller, Donald M., and Wiley David E. "Experimental Folklore and Experimentation: The Study of Programed Learning in the Wauwatosa Public Schools," Journal of Educational Research, 55 (1962), 485-494.

Levin, Gerald R. and Baker, Bruce L. "Item Scrambling in a Self-Instructional Program," Journal of Educational Psychology, 54, 3 (1963), 138-143.

Melaragno, Ralph J. "Effect of Negative Reinforcement in an Automated Teaching Setting," Psychological Reports, 7 (1960), 381-384.

Moore, J. William and Smith, Wendell I. "Knowledge of Results in Self-Teaching Spelling," Psychological Reports, 9 (1961), 717-726.

Pressey, S. L. "Development and Apprisal of Devices Providing Immediate Automatic Scoring of Objective Tests and Concomitant Self-Instruction," The Journal of Psychology, 29 (1950), 417-447.