Title: AN ANALYSIS OF THE EFFECTIVENESS OF A LEARNER-CENTERED TEACHING SYSTEM COMPARED TO THAT OF A CONVENTIONAL TEACHING OF BASIC ELECTRICITY TO UNIVERSITY STUDENTS

Abstract approved

Earl E. Smith

Purpose of the Study

The purpose of this study was to compare the effectiveness of a learner-centered teaching system and that of a conventional teaching of basic electricity to university students. For this study 65 students enrolled in basic electricity at Arizona State University in Tempe, Arizona were used, distributed in two fall semester classes as a control group, utilizing conventional teaching, and two spring semester classes as an experimental group, using the learner-centered teaching system.

All students participating in this study were given the Bell Laboratories Electricity Examination as a pre-test and as a final test. The Otis Test of Mental Ability was given to insure that each group
was comparable in mental ability.

Conclusions

The findings of this investigation supported the hypotheses that the experimental learner-centered teaching system was as effective as the conventional method used in teaching basic electricity. Furthermore, it was found that it proved to be significantly superior to the conventional method, both in the achievement of learning of electrical knowledge, and in the number of electrical experiments successfully completed by the students.

A step-wise linear regression program provided the necessary information to conduct tests for strength of relationship between the control and the dependent variables.

It was concluded that there was a relationship between the pre-test and post-test scores for both groups and that this relationship was stronger for the experimental group.

It was found that there was a strong negative correlation between the pre-test scores and gain in knowledge for both groups. The correlation between the post-test score and gain in learning was statistically significant for the control groups but not for the experimental group.

In the prediction equation of the step-wise linear regression program it was determined that group membership contributed to the prediction of the correlation between predicted post-test score and
observed post-test score. It was determined that there was a significant difference between the means of the experimental and control groups, and that pre-test scores contained predictive information while intelligence quotients did not.

The F statistic obtained from the analysis of covariance was determined to be statistically significant indicating a significant difference between the adjusted post-test score of the two groups.

The experimental group completed in excess of 20 percent more of the laboratory experiments than did the control group.

**Recommendations**

1. Additional studies of this experimental method should be conducted by different instructors in controlled situations in order to determine that the effectiveness of the system is transferable to other instructors.

2. Variables within the experimental teaching system should be examined statistically in order to improve upon the existing system and to add to the existing knowledge of learning processes.

3. Because the learner-centered teaching system was more effective than the conventional teaching method, it is recommended that this method be adapted to other subject areas and evaluated statistically.
An Analysis of the Effectiveness of a Learner-Centered Teaching System Compared to That of a Conventional Teaching of Basic Electricity to University Students

by

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A THESIS

submitted to

Oregon State University

in partial fulfillment of the requirements for the degree of

Doctor of Education

June 1971
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AN ANALYSIS OF THE EFFECTIVENESS OF A LEARNER-CENTERED TEACHING SYSTEM COMPARED TO THAT OF A CONVENTIONAL TEACHING OF BASIC ELECTRICITY TO UNIVERSITY STUDENTS

I. INTRODUCTION

Current efforts to initiate new teaching ideas in technical and vocational education are evidenced by a number of practices which have developed. As a result of some of these, significant changes in the organization of instruction and the role of the instructor have occurred. One of the newest developments to show promise has been the teaching system, briefly defined as "any complex of means, considered as a whole, designed to accomplish an instructional task" (21, p. 79).

While this describes teaching systems in general, such systems vary greatly due to differences in curriculum, individual teachers, facilities, instructional tasks, and other factors.

Teaching systems are quite young and, though more widely used in industry and the military services, they have begun to receive attention in general education. Due to the need for a quick, effective means of training personnel in a changing technology, industry has been utilizing this new method in its training programs with more frequency.

As technology has become more complex, the need for more
effective means of presenting the complex material to large groups of students has become increasingly important. Vocational educators need to understand the learning concepts involved and the uses of these systems and their relative effectiveness compared to conventional methods.

The Problem

The use of teaching systems in education has been relatively recent, and usually has involved the commercial, expensive types. The relative effectiveness of teaching systems must be clearly examined before educators can justify the expense or adapt themselves to the new teaching roles that the system involve.

Teachers differ in ability and the same teacher may vary from time to time as he becomes tired, ill, especially inspired or bored or bothered by personal problems. One of the major purposes of the teaching system is to provide an overall framework for later development and refinement so that other teachers and assistants who are working on specific aspects of the teaching program would have precise information of what had occurred. Usually a high degree of skill and ingenuity is needed to correct teaching deficiencies. The operation of a quality control segment of a teaching system could be very helpful if everyone involved has a clear idea of the rational of the system. Complete and constant interchange of information is a key
requirement that a teaching system can fulfill.

One may consider a teaching system as a framework designed to accomplish a carefully identified number of specific objectives. Many elements make up a system and may include films, tapes, slide demonstrations, experiments, and other teaching aids. Programmed instruction may also be included. Programmed instruction is usually not associated with large group teaching and is usually self paced. One goal of a teaching system is large group teaching and teacher pacing of lessons. This study is not an attempt to deal with programmed instruction extensively. In the last decade it was well established that programmed material can be helpful when properly used. Systems may also include models, guided discovery laboratory experiments and other techniques to manage students during learning. A quality control plan is an important part of a system to help maintain an objective evaluation of learning. All of these elements must be integrated with a carefully arranged plan. Important principles of learning should guide the choice of what to do and how to do it during the development period of a teaching system.

Essential functions provide the guidelines to construct a teaching system that will assure the desired objectives are obtained. One might consider the following:

1. The development of teaching objectives based on the performance of the task the student is to be taught.
2. Practice of task performance in a manner that will assure that the student has reached the objectives.
3. Practice of the components of task knowledge and skills.
4. Presentation of knowledge of the subject.
5. Control of student and teacher activity to accomplish maximum learning efficiency.
6. Knowledge of and control of teaching quality by means of an accurate and appropriate measure.

Statement of the Problem

The purpose of this study was to determine whether a significant difference existed between the effectiveness of a learner-centered teaching system and that of a conventional teaching of basic electricity to students at Arizona State University. If differences did exist, what were the nature and extent of the differences? Additional purposes of this study were to determine whether or not a significant learning difference existed between students of differing mental abilities.

Importance of the Study

Industrial technology at the university level has been expanding rapidly in an attempt to meet the needs of industry for well trained engineering technologists. The prospect of well paying jobs and job security has attracted students from many areas and fields in

1/ The following use of the term conventional teaching applies to the existing program at Arizona State University.
increasing numbers. The rapid advances of technology itself have added to the teaching difficulty. The fast growing mass of information to be taught requires constant revision to remain current. The industrial technology teacher has found himself with constantly increasing amounts of material to integrate into his course, larger classes of students eager to master the work and move on to waiting jobs in industry, and industry pressing for more graduates with the adaptability necessary to different areas within the industry. Thus, the most effective teaching methods must be found, developed and shared. Therefore, this analysis of the comparative effectiveness of a learner-centered teaching system on the university level is needed.

The findings of this study may provide a basis for the justification of the increased costs involved in the commercial systems. They may provide incentive to some educators to create their own teaching systems according to their particular needs. Information relative to the effectiveness of such programs may prove useful in encouraging the effort and the time required in the preparation and presentation of such systems.

Theoretical Framework

As a result of the rapid growth and needs of technology, and the resulting changes and needs in our society, there has been increased recognition of the need for education to find more efficient ways to
function. Much information has been gathered on programmed instruction, and some on teaching systems in industry or the military. However, further research needs to be done on the use of teaching systems applicable to the industrial technological level at universities.

**Basic Assumptions**

1. The university is assuming an increasing role in the preparation of students for employment in industry.

2. There is an increasing need for educators and educational institutions to examine and evaluate teaching methods relative to technology students.

3. Differences in effectiveness exist between learner-centered teaching methods and conventional methods.

4. Valid data relative to teaching effectiveness does exist and can be obtained.

5. Ranking on the Bell Laboratories Electricity Examination, measuring widely accepted mathematical principles of electrical theory, is a valid and reliable measure of teaching effectiveness.

6. The Otis Test of Mental Ability is a valid and reliable measure of intelligence considering the purpose to be to establish comparative difference only for this study.
Hypotheses

A learner-centered teaching system is as effective as the conventional method in providing basic electrical knowledge to Arizona State University students regardless of Intelligence Quotient or prior knowledge of the subject matter.

Procedure

This study was designed to compare the effectiveness of a learner-centered teaching system in a university course of basic electricity with a conventional course at Arizona State University. The study was conducted over a one year period. The control group consisted of two fall semester classes which contained a total of 32 students. The experimental group consisted of two spring semester classes which contained a total of 33 students. The following year, 1968-1969, the experimental system was conducted again during one spring semester and one summer class containing an additional 30 students. The purpose of this was to further check the reliability of the original experimental group.

The control group, taught by the conventional lecture-discussion method, used materials chosen from a list supplied by Electronic Industry Association for teachers. The experimental group, taught with a learner-centered teaching system, used a programmed text
with coordinated teaching media. Continual feedback was structured into the design of the course. Course organization and method differed while course content was identical. Both groups were taught by the same instructor. Groups were compared on the basis of goal achievement as well as examination scores. Group scores were computed by the Oregon State University Statistics Center using step-wise linear regression analysis of covariance.

Definition of Terms

In order to attain precision and clarity of meaning, the following definitions are included:

1. student: a student enrolled at Arizona State University in basic electricity.

2. experimental teaching system: the learner centered teaching system is intended to indicate that it places more responsibility for learning upon the student by means of an arranged series of activities, sequencing of instruction and managing students to achieve continual student participation. Teaching system refers to the aids and activities such as demonstration slides, experiments, projects, texts being designed to be a coordinated set so that each technique reinforces the other with almost identical material.

3. conventional method: basic electricity course taught by lecture-discussion with text and manual by different authors,
experiments, demonstrations, and projects from unrelated sources, except that all were chosen from the recommended list of the Electronic Industries Association Advisory Council. Examinations consisted of a mid-term and a final.
II. SURVEY OF RELATED LITERATURE

A review of the literature concerned with teaching systems has shown that few validated investigations have been conducted in this area. Therefore, in order to establish valid criteria for use in the study of this experimental teaching system, pertinent information has been gathered on the theory of teaching systems. Also, studies have been included on certain teaching methods pertinent to this experimental teaching system. These include such methods as programmed instruction as well as other specific instructional variables which were incorporated into the experimental teaching system. Furthermore, such data as could be found on existing systems used in a sustained educational environment has been presented.

**Theory of Teaching Systems**

Teaching methods in all levels of education have been changing and new methods have been introduced. Subject matter and the organization and presentation of it have been modified and developed. Increased teaching effectiveness has been the concern of educators at all levels. One of the newest methods to be developed has been the system approach, adapted from industry.
The Systems Approach

The true systems approach has been described by Corrigan, as a logical process of analysis and synthesis which provides a constant, on-going goal and performance evaluation, so that the system achieves up-to-date objectives. A well designed system should contain learner-oriented, behavioral objectives based on the true needs of the learner (16, p. 37).

E. M. Williams felt that the term, "systems approach" has been much overworked but that it is uniquely appropriate for describing a procedure in which every element in the overall educational operation must be considered in its relation to the other elements, proportioned and controlled, so that the performance of the whole is optimized (61, p. 490).

Description of the Systems Approach. According to W. W. Hanson, the engineering of instructional systems is the process of applying the principles and technology of programmed instruction to the planning, production, and implementation of an overall instructional system. The various instructional segments or sub-systems are completely planned and validated prior to inclusion in the total system (26, p. 45).

Much of the success of the teaching system is due to the continual feedback during the course of the program and to its adaptability
and flexibility (39, p. 74).

R. F. Mager has suggested that the systems approach is a matter of engineering human interaction just as circuit design is engineered. He has felt that known relationships should be researched, the situation evaluated for the relationships which would best apply, and then a solution, or system, designed. He has indicated further that when orderliness and cause-effect relationships are recognized as being important to the learning process, it will be recognized that telling is not teaching (43, p. 842-843).

**Development of a Teaching System.** The development of a teaching system, according to D. Engler, begins with the design of instructional methods in four main areas. First, objectives must be defined according to analysis of the relationship between subject matter content and student behavior. Second, pre-instructional behavior must be analyzed according to readiness, aptitude, and achievement. Third, methods and materials must be selected and developed in relation to the pre-instructional behavior and the desired performance and in relation to the intrinsic characteristics of the subject matter. Finally, evaluation of performance must be accomplished through criteria directly related to the objectives and tasks specified for a particular instructional situation rather than on a comparative basis with other students (18, p. 494).

The systems approach in any discipline, L. C. Silvern has
stated, has four characteristics which are often in sequential order. They are analysis of the problem, synthesis of elements and relationships into information, model construction for implementation, and simulation to reveal possible alternative solutions (55, p. 6).

Tracey, Flynn, and Legre, have suggested that a revision of the total curriculum, not isolated aspects of it, is essential to real improvement in education (58, p. 18).

**Benefits of the Systems Approach.** The benefits obtained by the Army through use of a systems approach to technical training have been listed by Tracey, Flynn, and Legre as increased objectivity even with daily procedures, improved morale among instructors, cost consciousness, additional skills including more familiarity with teaching skills as well as the material, and better utilization of personnel with special talents and specific experience. They indicate that studies must be complete, detailed, and objective, and faculty and staff must know the results of the feedback or the project will lose momentum (58, p. 21).

**Role of the Teacher.** A. A. Root has stated that "we cannot permit teaching to continue as an art which each instructor must develop in his own way . . ." but that teaching must now utilize all of the tools, techniques, and theories available. He suggests that the teacher's role, while using the vital, pertinent new media and theories, consists of a continuous decision-making process while
interacting with the students (51, p. 836).

**Role of the Student.** In a report of a conference on system approaches, sponsored by the University of California, the American Association of Junior Colleges, and the Accrediting Commission for Junior Colleges, S. N. Postlethwait stressed the importance of the role of the learner. He suggested that if the learning was to be done by the learner, then the teaching system must provide student involvement. His ideas for student involvement concern intelligent repetition, isolated concentration away from distractions, association with the subject or a model of it, adapting the communication method to the objectives, use of multimedia, and integrated learning activities and situations. These, he suggests, provide for student involvement in the true teaching system (47, p. 48).

**Some Misunderstandings.** Today, in the opinion of D. Engler, there remains distrust among teachers and parents that educational technology, or machines, will dehumanize education. These people tend to feel that the machines will eliminate vital human emotional and intellectual factors from education. Another fear, among some educators, is that such technology threatens their economic security and that most of the teacher's function will be turned over to machines, reducing the number of teachers needed to lower the cost of education. Perhaps the most difficult source of hostility toward educational technology is that it stresses measurable results from visible
instruction. Traditionally, the self-contained classroom was the teachers' domain. Opening both the educational program and the teaching process for inspection by all is a threatening prospect to many teachers (18, p. 495).

The very term "system" to describe an educational process is misleading to the extent that it conveys a regular, channelized, static response to particular situations. The task is more difficult and creative than simply following procedural outlines, according to J. H. McIntosh (44, p. 19).

H. J. Hartley has identified a number of possible current shortcomings in the methodology of systems analysis, emphasizing that systems procedures are a means not an end. After listing 25 common defects of systems analysis, he has concluded that the limitations are far outweighed by the potential advantages to be gained. The success of systems procedures depends upon the skill of the user (28, p. 519).

Use of Programmed Instruction in Systems Approach

The teaching system has developed from and around programmed instruction and is essentially a programmed multi-media program of participation. Hence, many of the aspects of programmed instruction are closely related to the systems approach.

Assessing Instructional Programs. A. A. Root has suggested important aspects to check when reviewing programmed instruction
material such as the specification of input and output characteristics, data on student performance, realistic problems, short learning episodes, and control of the flow of information (51, p. 836).

Research has yet to make programmed instruction a mature science. According to A. A. Lumsdaine, generalizations about methods not based on evidence, unsupported claims about program effectiveness, and data advanced for claims which actually fail to support in terms of accepted standards of scientific evidence must be cleared away. Tested performance specifications for current programs will allow research emphasis to shift toward the sciences of curriculum and instruction (42, p. 312-313). B. F. Skinner has emphasized that educational research on the experimental analysis of behavior leads to better understanding of the educational processes involved than generalization on improvement in student performance, no matter how important the latter are (56, p. 17).

The practice, review, and retention of academic subject matter needs more help from experimental psychology and requires laboratory and educational investigation, in the opinion of R. Glaser (23, p. 794). He has hypothesized that the greatest influence on the educational process will be in the areas of goals set in terms of observable, measurable student behavior, better definition and diagnosis of student strengths and weaknesses before instruction, significant changes in the techniques and materials employed by the teacher, and greater
stress on assessment of the outcomes of the programs (23, p. 804). Furthermore, he has felt that research on sustained educational environments will increase as will the measurement of long-range effects on retention and transfer (23, p. 805).

The final report of the American Society for Engineering Education on the ASEE Programmed Learning Project concluded that the principles of behavior can be learned and applied in the production of programmed instruction material. Furthermore, the report indicated, success will not come from the use of a single technological innovation but it can come when an overall systems approach is used in the blending of educational media and resources into a dynamic, changeable educational program (50, p. 874).

Sustained Educational Environment Systems

J. L Hughes concluded that the studies conducted on IBM programmed instruction indicated that effectiveness was not lost when used by succeeding classes totaling 199 trainees at a company training center over a period of nine months. Findings also showed that changes improving the efficiency of the original horizontal programmed text format were possible without reducing learning achievement. Trainee attitude suffered some as classroom time was reduced to 47% of the original class lecture period, although the level of dissatisfaction was reportedly low (37, p. 172-176).
J. S. Harmon, in a study on the effects of a multi-media environment in college level electronics, concluded that the nature of the achievement distribution, which differed markedly from that of a normalized curve, suggested that multi-media environment may not be suited for all learners. Possible causes for low achievement were identified as perhaps lack of knowledge of how to study, variations in the transition time in adapting to media, insufficient motivation from the media environment, and learners who refused to accept the responsibility of learning on their own. Select factors, measured by the EPPS and GATB scores, were capable of statistically limited prediction of achievement within a multi-media environment. Select factors, as measured by EPPS and GATB scores were capable of identifying means by which learners differ in selection of types of media. It was suggested that future media offerings must accommodate differences among individuals. Disadvantages, as listed by the learners, consisted of inefficiency in the use of time, difficulty in adjusting to new media and methods of instruction, the need for more frequent instructor presentations, and the need to daily inform the learner of his progress. Advantages of this method were fairness of tests and enjoyment of learning responsibility. Learners tended to agree that group study activities provided more interest than individual study would have. Negative feelings toward continuing use of multi-media in the program were expressed by 39.9 percent of the learners.
D. Allen, B. J. Hahn, Milo P. Johnson, and R. S. Nelson, in an evaluation of "Polysensory Learning through Multi-Media Instruction" as conducted at Mt. San Jacinto College, California, explained a teaching system designed to stimulate polysensory learning through a variety of devices and materials. It described the use of multi-media instructional materials in Trade and Technical Teacher Education and in Auto Mechanics and Auto Body and Fender Repair classes. In this method, the individualized multi-media instruction, most of the teacher-lectures, and some of the classroom demonstrations were replaced by commercially prepared or teacher-designed filmstrips, audio tapes, and worksheets, in an integrated presentation, and used by each student in a study booth. This was an individual student station which provided a degree of privacy and isolation from distraction.

Bruce Monroe conducted a study of seven colleges across the United States that were using some variation of multi-media instruction for academic subjects. In an unpublished report to the faculty of Mt. San Jacinto College, he stated that material programmed and taught with ideal teacher effectiveness could, theoretically, make a 40 percent difference in the learning over which the school had some control. He further stated that the average class using traditional methods would have about 75 percent of the students achieving about
75 percent of the goals. In his analysis of the courses taught with the above individualized multi-media instructional system at Mt. San Jacinto College, he found that 85 percent of the students achieved 80 percent of the goals. There was high correlation in results for all students in the trade-technical teacher education summer program at both mid-term and final examinations. The experimental group appeared to have a slightly higher overall level of achievement. On a Fisher "t" test, there was no significant difference between the two groups. Evaluation of Auto Body and Fender Repair course had not been completed (45).

**Systems Development within the University**

A study conducted at Michigan State University in 1963-1965 on **A Procedural and Cost Analysis Study of Media in Instructional Systems Development**, resulted in the development and field testing of an organization and operation which could serve as a model instructional development system. This became a demonstration and evaluation project for the development of instructional systems in a Health, Education and Welfare Contract, and was conducted at four participating universities during the years 1965 to 1967. These schools, Michigan State University, University of Colorado, San Francisco State College, and Syracuse University served as working models for instructional systems developed in their area, as well as providing
feedback data to the feasibility and reliability of the trial system (8, p. 1).

**Teaching Methods Pertinent to the Experimental System**

Due to the fact that the experimental teaching system was composed of programmed instruction variables incorporated into the system by means of a variety of media, some studies have been included involving programmed instruction and some of these variables. Many studies reporting no significant differences as well as many other studies not directly related to the teaching methods involved in the experimental system have not been included.

**Related Research on Programmed Instruction**

Two studies have been found which compare different forms of programmed instruction. In both of these, findings of no significant differences were reported. In one of these, H. O. Holt and J. Hammock conducted a study of the relative effectiveness of programmed books and simple teaching machines, involving 63 telephone company technicians in a program of 2,600 frames on basic electricity, and found no significant difference between the two methods (33, p. 50-56). In the second study mentioned, Arnold Roe compared seven branching and sequencing methods. He reported that, while there were differences between the branching procedures, the branching
procedures were not superior to linear sequencing (48, p. 407-416). Therefore, according to these studies, it could be assumed that the differences within programmed instruction are either negligible or too fine to be adequately measured at this time.

**Programmed Instruction Versus Conventional.** Six studies have been found comparing programmed instruction to various conventional forms. In a report to the Bell Telephone Laboratories, H. O. Holt and C. G. Valentine described an exploratory study of the use of a self-instruction program in basic electricity. The course covered a large block of instruction in basic electricity. The program was considered successful according to the time and proficiency of those taught by self-instruction versus those taught by conventional instruction. According to two final examinations given immediately after training and six months later, the program-taught trainees were significantly better (34, p. 1-27).

Furthermore, in an International Business Machine study on programmed instruction, the experimental classes covered the programmed material within the allotted 11 hours of classroom time, thereby saving 27 percent in classroom presentation time; only 11 percent of the experimental group scored below 90 on the examination compared to 55 percent for the control group (37, p. 172-176).

J. Engstrom and J. C. Whittakers conducted a study involving 60 college students randomly divided into two groups on a spelling
The experimental group used a teaching machine and a spelling program covering the words used in the pretest. The control group studied these words visually for the same amount of time. Both groups showed improvement, but the machine group showed more than the study group, and its retention after a month was higher (19, p. 125-126).

J. L. Evans, R. Glaser, and L. E. Homme presented programs in symbolic logic to six groups. They concluded that systematic programs using the Ruleg system produced equal proficiency in less time than less systematic programs (20, p. 433-452).

J. L. Hughes and W. J. McNamara prepared programmed texts covering the first 15 hours of a 16-week course on computer servicing. An experimental group using the programs made higher achievement test scores in less time than the control group, which was taught by lecture and discussion (38, p. 225-231).

Arnold Roe compared various automated procedures and lectures using elementary probability as content. Automated procedures included multiple-choice teaching machines, free-response teaching machines in a classroom, programmed texts requiring overt responses and providing correct answers, and programmed texts requiring no overt responses. Lectures included a "programmed" lecturer and a standard lecturer. There was no significant differences between any of the programmed methods, but all programmed methods
were superior to the standard lecturer (49, p. 198-201).

In all of these studies, programmed methods were found to be to some degree superior to the conventional methods involved.

Programs Combined with Conventional Versus Programs. Interestingly, three studies compared combination programmed instruction, and conventional instruction, with programmed instruction alone, and found the combination superior.

A study of programmed instruction versus conventional classroom teaching by R. O. Brown involving high school mathematics proved that the experimental group using programmed instructional materials in combination with the conventional teaching was superior to conventional classroom teaching in a test of general ability. The level of superiority was maintained in eight out of nine achievement tests given during the school term (8).

D. S. Bushness, in an experimental study in continuing education involving electricity for journeymen and a program for a branching-type teaching machine, found that the combination of auto-plus live instruction produced higher student satisfaction and higher subsequent enrollment, while the auto-instruction alone was most effective for the students scoring above average on the pretest (11).

Goldbeck, Shearer, Campeau, and Willis, gathered data on the effectiveness of programmed material integrated with classroom teaching versus classroom teaching without programmed material
indicates that a few minutes a day of programmed instruction inte-
grated with conventional classroom teaching could raise student per-
formance significantly higher than conventional teaching alone (25).

Program Combinations Versus Conventional. While these three
studies found programmed instruction in combination with conventional
superior to programmed instruction alone, one study was found which
reported that programmed instruction in combination with conventional
methods was superior to the conventional method alone. D. J. Klaus
and A. A. Lumsdaine found that programmed materials supplementing
the Harvey White physics telecast on elementary physics produced a
significant gain in the amount of learning over the control group without
the programmed materials (40).

Another study, conducted by E. C. Dowell, reported the pro-
grammed instruction combined with practice was superior to pro-
grammed instruction alone. An evaluation of trainer-testers was
conducted using 26,000 sets of programmed materials covering
trouble-shooting with the superheterodyne circuit. The group which
studied and practiced on both the programmed material and equipment
learned most, while the group studying and practicing on programmed
material only did no better than the group that received general instruc-
tions and did not practice (17).

A study conducted by J. H. Cantor and J. S. Brown reported
that the use of models seemed to effect practical learning while
programmed instruction seemed to effect intellectual learning. In the comparison of the traditional Navy method of training in electronics using mockups of actual equipment, with the same material presented by a punchboard tutor and by a trainer-tester, the traditional method resulted in superior laboratory work in some instances, while the self-instruction groups were superior in some intellectual aspects (12).

**Program Variables.** G. W. Angell, in a study of 162 college students using test items on chemistry designed for punchboard, found that students who secured immediate knowledge of results through use of the Angell and Troyer punchboard had significantly higher final examination scores than the students who learned of results at the next meeting (3, p. 391-394).

In another study involving immediate knowledge, as presented in the Preliminary Research Report of the Corrigan Telecommunication System, results indicated that the group which responded to each of the questions by pressing one of a number of buttons, and received immediate knowledge of the results, performed significantly better on a posttest than did either the group which responded by marking on IBM answer sheets or the group which neither received questions nor made responses (59, p. 1-23).

Both of these studies seem to indicate that immediate knowledge of results, or feedback, was superior. Another study indicated that feedback combined with discussion was superior to other methods.
Bryan and Rigney gathered data on the effectiveness of different modes of reinforcement involving college R.O.T.C. students and multiple-choice items in shipboard operations which showed that the groups given immediate knowledge of scores and an explanation did significantly better than either of the other groups who were given no knowledge or immediate knowledge but no explanations (9).

A study concerned with spaced reviews was conducted by R. Glaser and J. H. Reynolds on the effects of repetition and review upon retention in a linear program which involved a 1,280 frame biology chapter from a linear general science program. The conclusions were that variations in repetition had no significant effects upon retention and learning when used in a linear program (24, p. 179-182).

Active responses were apparently substantiated as superior in a study by Hovland, Lumsdaine, and Sheffield. In the study of active versus passive responses while viewing a teaching film, it was found that the active responses were significantly more effective on both oral and written tests. The active-response procedure was significantly more effective for more difficult material, for less intelligent learners, and for less motivated classes (36).

Response mode and small steps were studied by Coulson and Silberman in a simulated teaching machine. Multiple-choice response mode took less time than the constructed response mode, but there was no difference in achievement. Small steps required more time
but also yielded higher test scores than did large steps on the constructed response criterion test (15, p. 135-144).

Response mode was studied by J. B. Hough in a comparison of a teaching machine with conventional instruction. None of the three response modes—constructed, selected, or a combination of the two—was significantly more effective. Again, these results may be accepted or the differences considered too fine to be measurable at this time (35, p. 467-471).

E. L. Shriver, C. D. Fink, and R. C. Trexler conducted research on trouble shooting electronic weapon systems, using training methods based on some of the above mentioned variables. These were the three interconnected problems of developing training content based upon a cue-response paradigm, developing training and job methods and aids, such as mock-ups, substitute or obsolete equipment, and planning and managing personnel. The results of this study suggested that training based on these methods of analysis produced men capable of effectively performing the job with less training time than needed for traditional instruction in electronics maintenance (54, p. 96-98).

These training methods were not unlike the methods incorporated into the experimental teaching system, although involving a much shorter educational program.

Cost Comparison. A study on the preliminary cost comparison
of conventional and programmed-learning methods was conducted by F. F. Kopstein and R. T. Cave, concerning a 19 week course in communications electronics principles. It estimated costs in three different ways, and the costs of automated instruction compared favorably with those of conventional teaching, regardless of the method of estimation. Automated teaching, with a large initial expenditure, had a diminishing cost as the number of students increased while costs per student of conventional teaching remained relatively constant (41, p. 18-19).

Summary

A survey of literature shows teaching systems have developed from the logical combination of programmed material and new media into an integrated approach with emphasis on student and teacher participation. Much information has been found on the theories, definitions, design, descriptions, uses, development, benefits, and roles involved in the systems approach. Also, much data could be gathered on individual programmed courses and programmed instruction in general, many aspects of which are closely related with or integrated into the systems approach.

However, little comparative research or analytical data involving significant statistical findings has been found on complete, validated teaching systems, utilizing student involvement, in a sustained
educational environment.

In spite of this, systems are currently being experimentally developed, used, and validated on all levels of education and training.
III. METHOD AND PROCEDURE

Experimental course development began in 1960, when the writer was teaching basic electricity at Ganesha High School, in Pomona, California. The range of student levels in these classes included low achievement students, rehabilitation students from a state juvenile rehabilitation center, and students planning to continue their education in electrical engineering.

Development of the Experimental Course

After evaluating publications from industry, military, and education, it was decided that the Navy program used in training low achievement youth was most appropriate. Because of a limited supply, only one set of this program was available from the local reserve training unit. However, this material was available in abridged form, published by Rider Publishing Company, and has been referred to as coming "as close to programmed instruction as you will find, except for the blank for responding" (37, p. 238).

The development of 900 slides from the complete Navy program was begun during the 1960 summer session at Oregon State University, in order to aid presentation of the material not covered in the Rider texts.

During 1961, the feedback worksheet, containing four progress
check points, was developed after various forms had been tried in the classes.

During 1963, the final development of the 51 page laboratory workbook was completed for Vector Electronics, Inc. These workbooks used Vector materials to build 15 experiments and 15 demonstrations developed from the Navy materials.

In October, 1963, a committee of industrial advisers conferred with school representatives and endorsed the new electricity program developed at Ganesha High School. Representatives from General Dynamics, Consolidated Systems, Marguardt, and Pomona Electronics, as well as Mt. San Antonio College were present.

Approximately 1000 slides were further developed and organized during the 1964 summer session at Oregon State University. Also, at this time, the Simpson Instrument Corporation supplied all of the electrical measuring equipment needed in the experimental course, some of which was redesigned for simplicity according to the specific needs of the program.

In 1965, the experimental system was used in final form during the summer session at Oregon State University. At this time, it was used to teach basic electricity and methods to teachers, who were also furnished copies of the media used in the system for use in their own classes. During this time, the Bell Telephone examination was obtained for use as validating criterion in the system.
In 1966, the system was used to teach future technicians enrolled at Lane Community College, Eugene, Oregon. However, student enrollment was not large enough to furnish a reliable sample for a full statistical evaluation of the program.

In 1967, the workbook was expanded to 24 experiments and 24 demonstrations to accommodate the faster learning pace of university students. The evaluative study was then conducted at Arizona State University. The control group was taught during the fall semester, and the experimental group was taught during spring semester. The following year, the experimental study was repeated in order to check the reliability of the original experimental group.

**Design of the Study**

This study was designed to compare the effectiveness of a learner-centered teaching system in a university course of basic electricity with a conventional course at Arizona State University. Two groups were selected for the study. These groups consisted of four classes with a total of 65 students. The control group, consisting of two fall semester classes which involved 32 students, was taught in the conventional method using the industry recommended sources and materials. The experimental group, consisting of two spring semester classes involving 33 students, was taught by the experimental teaching system.
The conventional program was chosen by senior teachers in regard to suggestions for text, laboratory manual, demonstrations, and experiments. These had been initially chosen from a list of recommended materials by the Electronic Industry Association. The experimental teaching system consisted of programmed text by Rider, adjunctive auto clue designed by Pressey for use with this text, slides, workbook, demonstrations, experiments, and projects all keyed to the programmed text. Coordinated tests by Rider, designed expressly for feedback, were used.

Course organization was similar for the two methods in that the conventional method consisted of the lecture-discussion with the same demonstrations, experiments, projects, and course outline as the experimental system method. Course organization differed in that the conventional method did not use identical materials and the laboratory manual, demonstrations, and projects were not keyed to the text book.

Classroom organization differed in that the control group met two days a week for 45 minutes of lecture-discussion with note-taking required, and a mid-term examination was given containing questions taken from the text. The experimental group which met two days a week for 50 minutes consisted of 10 minutes of keyed slide presentation, with note-taking required, followed by a question and answer period, general discussion, and either a keyed quiz given or handed
back and discussed. The laboratory period consisted of three hours once a week for both groups. The conventional group worked four to a work station on experiments by Zbar, following demonstrations from the Crow package. The combination notebook-workbook was handed in at the end of the course. The experimental group worked four to a station, from a workbook keyed to the text, with worksheets which were checked at each step of each experiment. Demonstrations keyed to the text and the experiments were given. Students having difficulties in the laboratory were encouraged to review the appropriate slides as they felt the need. The keyed workbook was handed in at the end of the course.

Prior knowledge and goal achievement were determined by means of the standardized examination of basic electricity principles, designed by Bell Laboratories (see Appendix).

Students from the experimental and control groups were matched according to intelligence in order to assure similar group abilities.

To control the Hawthorne effect, both groups were told that they were participating in a study, but not whether they were the experimental or control group. Furthermore, both groups were taught the same course content by the same teacher, in the same facilities, for the same number of university credits.
IV. ANALYSIS OF DATA

Original data were collected to determine the effectiveness of a learner-centered teaching system compared to the traditional teaching of basic electricity to college students at Arizona State University. A step-wise linear regression program was used to conduct the basic analysis of the data, which included an analysis of covariance. Due to the fact that step-wise linear regression has not yet been widely used, the process has been examined in some detail in the following sections.

Control Variables

Control, or independent, variables consisted of measures of intelligence and preknowledge of electricity. The measurements were taken prior to the study so that the post test means of the control and experimental groups could be adjusted for differences in prior abilities before being tested for statistical differences. The step-wise linear regression program provided the necessary information to conduct tests for strength of relationship between the control and the dependent variables. Control variables having negligible relationships would be removed from subsequent analysis.
Criterion Variables

Proficiency in basic electricity was measured immediately after completion of the course by using the Bell Laboratories Basic Electricity Examination. This measurement was used as the criterion, or dependent, variable in the statistical analysis of the effectiveness of the two methods of teaching electricity. This analysis was conducted in the following manner.

The step-wise linear regression program used to carry out the covariance analysis in this study involved, first, the use of the two independent variables, intelligence quotients (Otis Self Administering, etc.) and previous knowledge of electricity (Bell Laboratory Test) has been mentioned. Dependent variables which should have affected the amount of learning, but which were impossible to isolate and observe, were treated by the use of a model equation. The purpose of this was to examine which of the independent variables, intelligence quotients and prior knowledge of electricity, contributed to the dependent variables, and to drop those which did not contribute. A basic requirement of this model equation was that all underlying assumptions be satisfied, particularly the variation caused by lack of knowledge about the other independent variables. Upon approximate satisfaction of the assumptions involved, statistical testing for the degree of contribution was possible. In this case, it was desired to test the
contribution of $X_1$, or the membership in the control or experimental
group, toward the prediction of $Y$ or the post test score. This was
considered to be the same as testing to find if $\beta_1$, or the constant
depending on whether the individual student was in the experimental
or control group, was equal to 0.

Mode of Equation

The model formula used was $Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta$

wherein

$\beta_0$ - mean final test score for all groups
$\beta_1$ = constant depending on whether the individual student
was in the experimental or control group.
$\beta_2$ = constant related to intelligence quotient of student
$\beta_3$ = constant related to the pre-test score
$\beta$ = error term

$X_1 = -1$ if individual was in control group
$+1$ if individual was in experimental group

$X_2 = I. Q.$ score of individual
$X_3 = pre-test score of individual$

The regression program provided estimates of the constant $\beta_0$, $\beta_1$,
$\beta_2$, $\beta_3$ -- the estimate will be designated by $b_0$, $b_1$, $b_2$, $b_3$. These
estimates were used to test the strength of relationship between the
covariates $X_3$ and $X_3$ to the dependent variable, and also the
difference between group means. The latter test was considered equivalent to testing to find if the constant associated with group membership ($\beta_1$) was equal to zero.

**Assumptions Involved in Step-wise Linear Regression**

One assumption was that the two groups were random samples from the student population of students who had taken or would take introductory electricity courses. Also, it was assumed that the students had been randomly placed into either the experimental or control group. While it was not possible to statistically satisfy these assumptions, it should be mentioned that neither group was informed of the study until after the course had begun, and neither group was told whether it was the experimental or control group. Therefore, it was hoped that the Hawthorne effect was minimized and that the samples behaved in a manner similar to a random sample.

Another assumption which was involved was that the error term was a random variable which had normal distribution with a mean of 0 and the variance of a random variable or $\beta^2$. This was tested statistically, by using tests for skewness and kurtosis of the distribution of deviation of the predicted from the observed. These tests have been placed in Appendix H. Under the hypothesis that the skewness was zero, it was found that $g_1$, or the coefficient of skewness, was smaller than the critical value of .475 at the .05 level. Therefore,
it was concluded that skewness of distribution was not different from zero.

From the test for kurtosis, it was concluded that $b_2$, or the curve criterion for kurtosis, was larger than the lower .05 critical level of 2.2 and smaller than the upper .05 critical level of 3.9. It was concluded that there was no appreciable deviation from normal distribution. Therefore, the error term was considered a random variable which had a normal distribution.

**Correlations from the Step-wise Linear Regression Program**

In the step-wise linear regression program, five variables were considered. These were, as has been previously stated, $X_1$ or individual membership in the experimental or control group, $X_2$ or intelligence quotient, $X_3$ or pre-test score, $X_4$ or $Y$ or post-test score, and $X_5$ or gain in test scores. Correlations between these variables were calculated, excepting $X_1$, a dummy variable used in this process. Intercorrelations for the control group and the experimental group as determined by the step-wise linear regression program have been presented in Table 1.

The correlation between the pre-test scores and the post-test scores for the control group was .418. As this correlation was significant at the .05 level, it was therefore concluded that there was a positive correlation between the pre-test score and the post-test
score for the control group. The correlation between pre-test scores and post-test scores for the experimental group was .757. As this was significant at the .01 level, it was therefore concluded that there was a positive correlation between the pre-test score and the post-test score in the experimental group.

Table 1. Intercorrelations for Control and Experimental Groups

<table>
<thead>
<tr>
<th>Correlated Variables</th>
<th>Control Group N = 32</th>
<th>Experimental Group N = 33</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intelligence quotients vs. pre-test</td>
<td>.605 not signif.</td>
<td>.16 not signif.</td>
</tr>
<tr>
<td>Intelligence quotients vs. post-test</td>
<td>-.0617 not signif.</td>
<td>-.0406 not signif.</td>
</tr>
<tr>
<td>Intelligence quotients vs. gain</td>
<td>-.1129 not signif.</td>
<td>-.2903 not signif.</td>
</tr>
<tr>
<td>Pre-test vs. post-test</td>
<td>.418 .05 level</td>
<td>.757 .01 level</td>
</tr>
<tr>
<td>Pre-test vs. gain</td>
<td>-.6003 .01 level</td>
<td>-.6937 .01 level</td>
</tr>
<tr>
<td>Post-test vs. gain</td>
<td>.475 .01 level</td>
<td>-.0547 not signif.</td>
</tr>
</tbody>
</table>

The correlation between the pre-test scores and the gain in test scores for the control group was -.6003. As this was significant at the .01 level, it was therefore concluded that there was a strong negative correlation between the pre-test score and gain in test scores for the control group. The correlation between pre-test scores and gain in learning for the experimental group was .6937. As this was significant at the .01 level, it was therefore concluded that there was a negative correlation between pre-test and gain for the experimental group.

The correlation between the post-test score and gain in learning for the control group was .475. As this was statistically
significant at the .01 level, it was concluded that there was a positive correlation between the post-test scores and gain in learning for the control group. The correlation between post-test scores and gain for the experimental group was -.0547 which was not considered to be statistically significant.

General Conclusions about the Intercorrelations

One should not be enthusiastic about conclusions drawn from correlations of small groups because they are susceptible to minor fluctuations. However, they may be helpful in giving some insight into the research.

It would appear that intelligence quotient scores had no relationship with pre-test scores or post-test scores. Neither did they have relationship with gain in learning for either group, although the negative correlation with gain was much stronger for the experimental group than the control group. This might possibly be an indication that poorer students, with lower intelligence quotients, had a slightly better gain in learning in the experimental group than in the control group.

Furthermore, pre-test scores had a positive correlation with post-test scores for both groups, although the relationship was much stronger for the experimental group than for the control group. An explanation for this might be that the experimental method moved the
members of the group through the material at a steadier pace, so that at the end of a specific period of time, all students had advanced a certain amount.

Pre-test scores had a negative correlation with gain on tests for both groups. This would indicate that students with higher pre-test scores achieved a smaller gain in learning than did the students with lower pre-test scores.

Furthermore, post-test scores had a positive correlation with gain in learning for the control group but not for the experimental group. This might suggest that in the traditional approach, a high final score would indicate high gain, whereas in the experimental approach, gain is much the same over all the post-test scores.

**Step-wise Linear Regression or Prediction Equation**

The steps involved in the step-wise linear regression were the stages in which a prediction equation was developed. By this means, the independent variables were examined in order to select the variable which contributed the greatest reduction in unexplained error.

It should be noted that two different types of variables were used in the study. One was a quantitative variable, such as the pre-test score of $X_3$, which took on values somewhere between 0 and 100. The other type of variable was qualitative, taking on only two values, such as $X_1$, or membership of the individual in a group. $X_1 = -1$
and \( X_2 = +1 \) was used in the program to distinguish the groups.

Two measures of how well the total variation was explained were possible. The square of the relationship between two variables, \( R^2 \), was one method, with higher measures indicating higher relationships. The standard deviation of the predicted value of the post-test score, or \( Y \), was the other method of measurement, with smaller measurers indicating higher relationships.

The first step of the step-wise linear regression produced a prediction equation that stated that the predicted value of the post-test score was equal to the constant plus the correlation coefficient of the pre-test score and the post-test score. This equation produced a standard deviation of the predicted value of the post-test score of 8.54. The square of the correlation or \( R^2 \) between the observed post-test scores and the predicted value of the post-test score was .323.

The second step of the program introduced group membership into the equation with the result that the square of the correlation produced was .478, and the standard deviation of the predicted value of the post-test score was 7.62. Thus, it was noted that the correlation between observed post-test score and predicted post-test score increased appreciably with the addition of an extra variable, while the standard deviation of the predicted value of the post-test score decreased. Therefore, it was evident that group membership
improved the prediction equation, or contributed to the prediction.

At this point the contribution of each variable was tested by using the students t value for each variable with the hypothesis that the constant for each variable was not equal to zero. The student t value for group membership was found to be 4.10, which exceeded the critical value of 2.00, calculated under the null hypothesis with 61 degrees of freedom. It was therefore concluded that the constant for group membership was not equal to zero, and that there was a significant difference, greater than the .001 level, between the means of the experimental and the control groups. In the same manner it was concluded that the pre-test scores contained predictive information.

The third step of the program added intelligence quotients to the predictive equation, with the result that the $R^2$ and the standard deviation of the predicted value of the post-test score did not change appreciably upon the addition of another variable. Hence, it was apparent that the extra variable of intelligence quotients was not contributing any information to the equation.

In the hypothesis test that the constant for intelligence quotients was equal to zero, the value of the t statistic was -1.09, which was within the acceptable range of -2.00 to 2.00 at the .05 level for a two sided test with 61 degrees of freedom. Therefore, intelligence quotients as a variable were dropped as it did not contribute information
for predictive purposes, and group membership and pre-test scores were retained as contributing variables.

Analysis of Covariance

The results of the regression analysis were then written in the usual analysis of covariance table since the dropping of intelligence quotients left only one covariable, $X_2$. The analysis of covariance uses pre-test scores as a covariable, and post-test scores as the dependent variable, and experimental and control groups as treatments. In order to summarize the findings, an analysis of variance summary is presented in Table 2.

Table 2. Analysis of Variance Summary Table

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>Degrees of Freedom</th>
<th>Mean Squares</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatments (between groups)</td>
<td>981.96</td>
<td>1</td>
<td>981.98</td>
<td>16.83</td>
</tr>
<tr>
<td>Error (within groups)</td>
<td>3,617.37</td>
<td>62</td>
<td>58.34</td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td>4,599.33</td>
<td>63</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The column labeled Sum of Squares contains the actual values of the sums of squares computed from the data. The Mean Squares column contains the values of the mean squares which were found by dividing the sum of squares by its degrees of freedom. The $F$ statistic was then formed from the ratio of the mean square between
groups to the mean square within groups. The F statistic, 16.83 was used to test the hypothesis that the adjusted means of the post-test scores for both groups were the same. The F statistic, when compared to the F distribution chart with (1, 62) degrees of freedom, was found to be larger than 8.49 at the .01 critical level. Therefore it was concluded that the adjusted means of the post-test scores for both groups differed significantly. The adjusted means of the experimental and control groups have been presented in Table 3.

Table 3. Adjusted Means of the Post-test Scores for the Experimental and Control Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Number in Group</th>
<th>Pre-test Means</th>
<th>Post-test Means</th>
<th>Adjusted Means</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>32</td>
<td>48.75</td>
<td>60.78</td>
<td>61.68</td>
</tr>
<tr>
<td>Experimental</td>
<td>33</td>
<td>52.60</td>
<td>70.45</td>
<td>69.57</td>
</tr>
</tbody>
</table>

Thus the post-test score means, when adjusted according to initial differences in the pre-test means, were shown to be 61.68 for the control group and 69.57 for the experimental group. Therefore, subject to possible limitations of assuming random samples, the experimental method was concluded to be much more effective than the control method.

Other Criterion Variables

Another criterion variable involved in the study was the analysis of group means of the quizzes according to the topics covered. It
should be noted that the quizzes were administered weekly to the experimental group, while the control group received the first six in the form of a test at mid-term and the remaining six as a test at the end of the course, before the administration of the final Bell Laboratories Basic Examination. The topical quiz means have been presented in Table 4.

Table 4. Topical Quiz Means for Experimental and Control Groups

<table>
<thead>
<tr>
<th>Quiz Number</th>
<th>Quiz Topic</th>
<th>Mean Scores of Experimental Group</th>
<th>Mean Score of Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fundamental concept of electricity</td>
<td>9.74</td>
<td>8.51</td>
</tr>
<tr>
<td>2</td>
<td>Static electricity and current</td>
<td>9.58</td>
<td>8.79</td>
</tr>
<tr>
<td>3</td>
<td>Magnetism and sources of EMF</td>
<td>9.12</td>
<td>8.06</td>
</tr>
<tr>
<td>4</td>
<td>Electromotive force, resistance and conductance</td>
<td>9.18</td>
<td>7.94</td>
</tr>
<tr>
<td>5</td>
<td>Ohms law, Kirchoff's laws</td>
<td>9.51</td>
<td>8.60</td>
</tr>
<tr>
<td>6</td>
<td>Basic electrical indicating instruments</td>
<td>9.60</td>
<td>8.43</td>
</tr>
<tr>
<td>7</td>
<td>Resistor combinations and basic circuits</td>
<td>8.75</td>
<td>8.79</td>
</tr>
<tr>
<td>8</td>
<td>Fundamentals of altering current</td>
<td>8.37</td>
<td>8.06</td>
</tr>
<tr>
<td>9</td>
<td>Inductance</td>
<td>7.95</td>
<td>7.94</td>
</tr>
<tr>
<td>10</td>
<td>Capacitance</td>
<td>9.33</td>
<td>6.91</td>
</tr>
<tr>
<td>11</td>
<td>Direct current motors and generators</td>
<td>7.93</td>
<td>7.95</td>
</tr>
<tr>
<td>12</td>
<td>Alternators and alternating current motors</td>
<td>6.90</td>
<td>6.90</td>
</tr>
</tbody>
</table>

The difference in presentation of the quizzes to the two groups may have resulted in benefit to the experimental group in that the material had been presented more recently and in reinforcing learning with a resulting higher retention at the time of the final examination.
However, each quiz had no effect upon the next quiz, other than perhaps providing a stronger foundation of the material already covered. Therefore, these quiz means were examined separately according to topic for variations between the two methods.

The group means on the first six of the quizzes for the control group were approximately one point lower than for the experimental group, including the sixth quiz which was administered directly after presentation of that topic in both groups. If the time element had been the influence on the lower score mean of the control group for those first six quizzes, that influence would not have held on the sixth quiz topic. Since the experimental group had a mean score of 9.60 and the control group had a score mean of 8.43 on the sixth quiz, it would seem that some other factor influenced the difference of the mean scores. The experimental group benefited from a more consistent use of the new electricity vocabulary in the material, or perhaps from the identical hardware employed in the system, or from the class time organization and management of students, or from all of these.

In the seventh quiz mean comparison, there was a distinct difference from the sixth. The experimental and control groups achieved almost identical score means. Since this material was presented soon after the middle of the term but was not tested in the control group until later while the experimental group was tested immediately,
the time element would not seem to be the reason for the similar scores. The topic covered on this test, resistor combinations and basic circuits, was somewhat different from the previous topics, however. This was due to the fact that the material involved here required more application of memorized formulas than theoretical application. Perhaps such material did not benefit from programming and multi-media as much as the more abstract material.

The eighth quiz, covering fundamentals of alternating currents, was over much more theoretically complex materials, yet both groups again achieved similar mean scores. Perhaps this could be attributed to the fact that all students except three members of the control group completed the experiments which reinforced the abstract concepts covered.

The ninth quiz, on inductance, a sophisticated theory involving much that could not be measured in the experiments, had similar test score means for both groups. Laboratory experiments were weak and failed to benefit the experimental group. Only three students from the control group completed these experiments.

The tenth quiz, on capacitance, showed wide divergence on the test means. The experimental group achieved 9.33 and the control group, only 6.91. Perhaps this difference was due to the completion of the well designed experiments by almost all of the experimental
group and only two of the control group.

The eleventh and twelfth quizzes were again similar in group test score means. None of the control group completed any of the matching experiments while three of the experimental group completed the eleventh experiments, and only one of the experimental group completed the last. Therefore, it might be possible that the effectiveness of the experimental method was lost in this instance.

This analysis of topical quiz score means involved interacting factors and some unknown influences. Therefore, it was necessarily a search for more apparent, probably influences.

Behavioral Goals Criterion

Laboratory work was another criterion variable examined in the study of the effectiveness of a learner-centered teaching system. A comparison of laboratory work completed by members of the experimental and control groups has been presented in Table 5.

The experimental and control groups both had 48 hours in the laboratory, divided into 16 weekly three hour laboratory sessions. The laboratory work for each group was very similar. Assuming that the students were similar in ability, and that the time spent on laboratory work was identical, and that the instructional content was similar, some other factor must have accounted for the fact that the experimental group completed in excess of 20% more of the laboratory
Table 5. Number of Students Completing Laboratory Experiments in Experimental and Control Groups

<table>
<thead>
<tr>
<th>Laboratory Experiment</th>
<th>Number of Students Completing Experiment in Experimental Group</th>
<th>Number of Students Completing Experiment in Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Electrical components and symbols</td>
<td>33</td>
<td>32</td>
</tr>
<tr>
<td>2. The schematic diagram</td>
<td>33</td>
<td>32</td>
</tr>
<tr>
<td>3. Soldering techniques</td>
<td>33</td>
<td>32</td>
</tr>
<tr>
<td>4. Use of the milliameter</td>
<td>33</td>
<td>32</td>
</tr>
<tr>
<td>5. Resistor color code and ohmmeter use</td>
<td>33</td>
<td>32</td>
</tr>
<tr>
<td>6. Ohms law</td>
<td>33</td>
<td>32</td>
</tr>
<tr>
<td>7. Characteristics of a series circuit</td>
<td>33</td>
<td>32</td>
</tr>
<tr>
<td>8. Characteristics of a parallel circuit</td>
<td>33</td>
<td>32</td>
</tr>
<tr>
<td>10. Voltage divider circuits</td>
<td>33</td>
<td>32</td>
</tr>
<tr>
<td>11. Potentiometers</td>
<td>33</td>
<td>32</td>
</tr>
<tr>
<td>12. Kirchoffs Laws</td>
<td>33</td>
<td>32</td>
</tr>
<tr>
<td>13. Voltmeter multipliers</td>
<td>33</td>
<td>32</td>
</tr>
<tr>
<td>14. Current meter shunts</td>
<td>33</td>
<td>32</td>
</tr>
<tr>
<td>15. Use and care of the VOM</td>
<td>33</td>
<td>32</td>
</tr>
<tr>
<td>16. Oscilloscope operation</td>
<td>33</td>
<td>30</td>
</tr>
<tr>
<td>17. Characteristics of an inductance</td>
<td>33</td>
<td>3</td>
</tr>
<tr>
<td>18. Inductances in series and in parallel</td>
<td>32</td>
<td>3</td>
</tr>
<tr>
<td>19. Capacitor color code and testing</td>
<td>31</td>
<td>2</td>
</tr>
<tr>
<td>20. Capacitors in reactance</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td>21. Capacitors in series and parallel</td>
<td>28</td>
<td>0</td>
</tr>
<tr>
<td>22. Resonant circuits</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>23. DC Motors and generators</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>24. AC Motors and alternators</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
experiments. It would seem that the materials by different authors used in the control group laboratory experiments not only failed to create a higher interest level, but actually required time-consuming familiarization with small, dissimilar details.

Repeatability Check on Experimental and Control Methods

Two repeatability check studies on the experimental method were conducted following the completion of the original study. One of these was taught again by the writer and the other was taught by a graduate assistant on the teaching staff at Arizona State University after receiving instructions. Data on the pre-test and post-test scores on the Basic Electricity Examination of the first repeatability check conducted the year after the experimental group was taught have been presented in Table 6.

Results in this course seemed similar according to post-test mean comparison. The post-test mean of the experimental group was 70.45 and the post-test mean of the repeatability check group was 71.69. This would give the repeatability check group a slightly higher post-test mean although the pre-test mean for that group, 38.69, was much lower than the pre-test mean for the experimental group, 52.60. Therefore, it would seem that the effect was repeatable in other groups.

The other repeatability check study was conducted by a graduate
Table 6. Distribution of Scores on Basic Electricity Examination During the First Repeatability Check (13 Students)

<table>
<thead>
<tr>
<th>Examination Scores (in Increments of 5)</th>
<th>Number of Students Scoring at This Level on Pre-test</th>
<th>Number of Students Scoring at This Level on Post-Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>76-80</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>71-75</td>
<td>0</td>
<td>(M-72)-- 3</td>
</tr>
<tr>
<td>66-70</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>61-65</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>56-60</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>51-55</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>46-50</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>41-45</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>36-40</td>
<td>(M-39)-- 4</td>
<td>0</td>
</tr>
<tr>
<td>31-35</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>26-30</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>21-25</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Pre-test mean 38.6923  Post-test mean 71.6923
Pre-test SD 9.2861  Post-test SD 6.3164
Pre-test reliability (KR-20) .7095  Post-test reliability (KR-20) .7049
Pre-test SE 4.2508  Post-test SE 3.4312
Table 7. Distribution of Scores on Basic Electricity Examination during the Second Repeatability Check (17 Students)

<table>
<thead>
<tr>
<th>Examination Scores (in Increments of 5)</th>
<th>Number of Students Scoring at This Level on Pre-test</th>
<th>Number of Students Scoring at This Level on Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>76-80</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>71-75</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>66-70</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>61-65</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>56-60</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>51-55</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>46-50</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>41-45</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>36-40</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>31-35</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>26-30</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>21-25</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>16-20</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>11-15</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6-10</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0-5</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

Pre-test mean 37.3500  Post-test Mean 60.7059
Pre-test SD 21.7601  Post-test SD 8.4096
Pre-test reliability (KR-20) 0.9706  Post-test reliability (KR-20) 0.8679
Pre-test SE 3.7319  Post-test SE 3.0561
assistant at Arizona State University during the summer session following the first repeatability check. The data from this study has been presented in Table 7.

Results in this course varied from the other courses involving the experimental method in the lower post-test mean, 60.7059, as compared to the others at 70.45 and 71.69, even though the pre-test means in all were similar. This study, conducted during summer session, unfortunately, was over a five-week course rather than the regular 16-week course. Furthermore, the students involved were perhaps not from the same population as the regular full time students, as some were older and many had full time jobs. This was perhaps evidenced by the large standard deviation in the pre-test score of this group, although the standard deviation in the post-test score was more normal. Therefore, it was concluded that the results of the second repeatability check were inconclusive due to the addition of new variables other than that of the different instructor.

The repeatability of the control method was checked by comparing final grades and project completion with the instructors of the course during the year previous to the study. They observed the level of achievement of the control group and were in agreement that the level of student achievement was similar to the groups they had taught.
Summary

The effectiveness of the experimental learner-centered teaching system in basic electricity was compared with the conventional method. Both methods covered similar material for the same periods of time. Analysis of covariance was conducted in order to adjust the post-test score means according to initial differences in the pre-test means. It was concluded that the experimental method was much more effective than the control method, subject to possible limitations of assuming random samples. Completion of laboratory experiments was also tabulated. It was found that the experimental group generally completed more of these. A repeatability check study conducted achieved similar results, while another study conducted by another teacher was inconclusive. Therefore, the question remains whether the potential effectiveness is readily transferable to other teachers and, also, to other subjects.
V. SUMMARY AND CONCLUSIONS

The purpose of this study was to determine whether the experimental learner-centered teaching system was as effective as the conventional method, in teaching basic electricity to Arizona State University students. A survey of related literature was conducted to establish a theoretical framework and provide guidance in the design of the investigation.

Two groups of students were selected for observation. The first group involved the 32 students enrolled in the two fall semester classes of basic electricity, and the second group included the 33 students enrolled in the two spring semester classes of basic electricity. The first group, or control group, was taught by the traditional method while the second, or experimental group, was taught by the learner-centered teaching system.

Original data was obtained by examining and evaluating the groups according to covariance analysis of pre- and post-test scores in a step-wise multiple linear regression. The covariance analysis was used to adjust the final scores corresponding to the bias due to pre-knowledge of the material in either group. Furthermore, behavioral objective records were analyzed by inspection. Two subsequent repeatability checks were made on the experimental learner-centered system.
A topic outline was followed carefully and used by both the control group and the experimental group to assure the same material was covered. All students participating in the study were given pre-tests to determine if the control group or the experimental group did or did not possess more knowledge of basic electricity than the experimental group.

With the help of John Taylor at the University Testing Service the Otis Quick Scoring Mental Ability Tests were given to determine if the two groups were comparable in mental ability. The test also was considered as a prediction of success in learning basic electricity but as the study proceeded it was shown that the IQ scores had no relationship with pre-test or post-test for either group.

All four classes met in the same classroom for two 50-minute classes each week for one 16-week term. To minimize differences, the two central group classes met together during the lecture and made one large class. The same treatment was followed with the experimental group. The laboratory session for each class met once a week for three hours. The same person taught all laboratories to assure laboratory conditions did not vary from the format.

Summary of Findings

The findings of this investigation have been summarized in three subdivisions: comparative effectiveness of the two teaching methods
used in this study, support of the findings in the analysis of other criterion variables, and support of the findings in the repeatability check studies.

Comparative Effectiveness of the Two Teaching Methods

Step-wise linear regression analysis of covariance was used to measure the comparative effectiveness of the two teaching methods. The regression analysis indicated that the independent variables of group membership and pre-test scores contained predictive information toward the post-test scores, while intelligence quotients did not.

One requirement of the study was to find a good existing program that could be taught the way it had always been taught before. Also, a chance population that was not too limited in purpose should be available. These two requirements were realized by choosing a large school with an already successful program. The Division of Technology at Arizona State University has students with many different major fields who take courses in basic electricity. For this study 65 second year students in basic electricity classes were chosen.

Two classes of Fall semester 1967 were taught exactly the same as the classes had always been taught. The two senior professors aided by agreeing to help with this to assure that the effort would be the same as those taught in previous years. These were called the traditional classes. The traditional classes used the same text
(Elements of Electricity by Timbe) as in previous years. The laboratory manual, Basic Electricity by Paul Zbar, was also the same and may be considered as a standard as it was selected by an electronic advisory committee from the Electronics Industries Association. The laboratory equipment used was the existing Crow demonstration equipment and Science Electronic Material without any changes.

A step-wise linear regression program provided the necessary information to conduct tests for strength of relationship between the control and the dependent variables. Those showing negligible relationships were removed from subsequent analysis in the program. The control, or independent, variables were measures of intelligence and preknowledge of electricity. The criterion, or dependent, variable was the basic electricity post-test.

The assumptions were that the students were a random selection and randomly placed in the courses, and that the error term was a random variable with a mean of 0 and the variance of a random variable. For the latter assumption, tests for skewness and kurtosis were conducted with the results supporting the assumption.

The correlation between the pre-test scores and the post-test scores for the control group was .418, significant at the .05 level, while the correlation between the pre-test scores and the post-test scores for the experimental group was .757, significant at the .01
level. Therefore, it was concluded that there was a relationship between the pre-test and post-test scores for both groups and that this relationship was stronger for the experimental group. An explanation of this might be that the experimental method moved the members of the group through the material at a steadier pace, so that all students had advanced a certain amount at the end of the course. As the premise of an instructional system is that it individualizes teaching more than traditional methods, it would seem that this had been accomplished.

The correlation between the pre-test scores and gain in test scores for the control group was -.6003, significant at the .01 level, and for the experimental group -.6937, significant at the .01 level also. Therefore, it was concluded that there was a strong negative correlation between the pre-test scores and gain for both groups. This would indicate that those who knew less at the beginning of the courses learned proportionately more in both groups.

The correlation between the post-test score and gain in learning was .475 for the control group, significant at the .01 level, and -.0547 for the experimental group, not considered statistically significant. This would indicate that in the traditional approach, a high final score would indicate high gain whereas in the experimental approach, gain was much the same for all.

In the prediction equation of the stepwise linear regression
program it was determined that group membership contributed to the prediction of the correlation between predicted post-test score and observed post-test score. Then the contribution of each variable was tested, using the student's t value and the hypothesis that the constant for each value was not equal to zero. In this manner it was determined that there was a significant difference between the means of the experimental and control groups. In the same manner it was concluded that the pre-test scores contained predictive information. When intelligence quotients were added to the predictive equation it was apparent that this variable did not add any predictive information to the equation. This variable was then dropped from the program.

Analysis of covariance was then conducted using pre-test scores as the dependent variable, post-test scores as the dependent variable, and the experimental and control groups as treatments. The F statistic was determined to be statistically significant to the .01 level indicating a significant difference between the adjusted post-test score of the two groups. These adjusted means were shown to be 61.68 for the control group and 69.57 for the experimental group. Therefore it was concluded that the experimental method was much more effective than the control method.

Analysis of Other Criterion Variables

Another criterion variable involved in the study was the analysis
of group means of the quizzes according to the topics covered. The group means on the first six of the quizzes for the control group were approximately one point lower than the experimental group, while the remaining six showed more fluctuation, due to a variety of possible causes. The means of the seventh, eighth, and ninth quizzes were almost the same for both groups. This might indicate the need for further development of the experimental teaching system at these points. On the tenth quiz, the experimental group mean was 9.33 and the control group mean was 6.91, while the eleventh and twelfth quiz means were similar for both groups. This could be explained by the fact that only two members of the control group completed the laboratory work for the tenth quiz while almost all of the experimental group completed this work. However, fewer of the experimental group completed the eleventh quiz-related work, and only one of that group covered the twelfth quiz-related work.

Yet another criterion variable examined in the study was a comparison of laboratory work completed by members of the experimental and control groups. The experimental group completed in excess of 20 percent more of the laboratory experiments than the control group. It would seem that the variety of materials used in the traditional method not only failed to create a higher interest level but also added unfamiliar details. Yet perhaps the organization of the experimental group allowed greater freedom in learning for those who could
proceed adhead of some of the others. Again, the combination of both of these factors might have been the most influential aspect.

Repeatability Check Studies

A repeatability check study on the experimental method, conducted the following year, achieved similar results according to comparison of post-test means. Therefore, it was concluded that the effect was repeatable in other groups using the experimental method.

A second repeatability check study, conducted by another staff member at Arizona State University during a summer session, also showed similar results in comparison of pre-test and post-test means, but since additional variables were added, the results were considered inconclusive. The control method was checked by instructors of the course during the year previous to the study. They agreed that the level of student achievement was similar to the groups that they had taught.

Conclusions

The findings of this investigation supported the hypotheses that the experimental learner-centered teaching system was as effective as that of a conventional method used in teaching basic electricity to Arizona State University students. Furthermore, it was found it proved to be significantly superior to the conventional method, both
in the achievement of learning of electrical knowledge, and in the number of electrical experiments successfully completed by the students.

Recommendations

The need for continued study and additional research is indicated in several areas. The experimental method should be conducted again by a different instructor other than the writer in a controlled situation in order to determine that the effectiveness is transferable to other instructors. Also, variables within the experimental teaching system could be examined in order to improve upon the existing system and perhaps to add to the existing knowledge of learning processes. Variables which might be examined could include different arrangements of the social structure within the classroom, possibly using individual carrolls instead of the four-man work station. Another area of study should include the use of individual score cards or punch-out cards in place of the quizzes for more immediate feedback. These would provide knowledge of results and would replace group discussion. A possible investigation might be replacement of the slides with the lecture-discussion method incorporating programmed instruction in all levels. Another possible investigation might be to replace group viewing of the slides with individual viewing machines for complete self-pacing.

Broader evidence of the effectiveness of this learner-centered experimental teaching system would be the adaptation of the
construction methods and variables involved to other subject areas and the comparative evaluation of those systems.
BIBLIOGRAPHY


59. Vicory, Arthur. Preliminary research report of the Corrigan telecommunication system. 23 p. (Place of writing or publication unidentified.) 1963. (Ditto)


APPENDICES
APPENDIX A

Topic Outline for Both Courses
ELECTRICITY

1. WHAT ELECTRICITY IS
   molecule--atom--nucleus--neutron--
   proton--electron electricity definition

2. HOW ELECTRICITY IS PRODUCED

3. HOW FRICTION PRODUCES ELECTRICITY
   negative charges--positive charge--
   repulsion of charges--attraction of
   charges--static electricity--friction
   charge--contact charge--induction
   charge--contact discharge--arc dis-
   charge

4. HOW PRESSURE PRODUCES ELECTRICITY
   electric charges from pressure and
   pressure from electric charges--how
   a crystal works--crystal cartridges

5. HOW HEAT PRODUCES ELECTRICITY
   thermo--couple

6. HOW LIGHT PRODUCES ELECTRICITY
   construction of photo cell--
   measuring light intensity

7. HOW CHEMICAL ACTION PRODUCES
   ELECTRICITY--PRIMARY
   how primary cells are used--what a
   primary cell is--parts--how a pri-
   mary cell works--testing dry cells--
   changing dry cells--connections in
   series or parallel--symbols

8. HOW CHEMICAL ACTION PRODUCES
   ELECTRICITY--SECONDARY
   definition--maintenance--how
   storage batteries are checked--
   how storage batteries are charged

9. HOW MAGNETISM PRODUCES ELECTRICITY
   electric power from magnetism--
   definition--magnetic fields--cutting
   a magnetic field

10. CURRENT FLOW--WHAT IT IS
    electrons in motion--direction of
    current flow--relationship between
    voltage, current and resistance--
    ammeter

11. MAGNETIC FIELDS
    flux line density

12. HOW CURRENT IS MEASURED
    how electric charges are measured--
    units of current flow--measurement--
    small current--units of current change--
    milliammeters and microammmeters--
    reading meter scales--usable meter

range--ammeter ranges--parallax--
interpolation

13. HOW A METER WORKS
    basic movement--considerations--
    range changes--ammeter shunts--
    multi-range ammeters--shunting
    meters by comparison--shunting
    meters by multiplication

14. WHAT CAUSES CURRENT FLOW EMF
    definition--maintenance--voltage
    and current flow--volt meter use--
    demonstration of voltage

15. HOW VOLTAGE IS MEASURED
    units--changing units--voltmeter--
    changing voltmeter ranges--multi-
    range voltmeters--voltmeter ranges--
    multipliers

16. WHAT CONTROLS CURRENT FLOW--
    RESISTANCE
    definition--conductors and insulators--
    factors controlling resistance material-
    length--cross-sectional area--tempera-
    ture--units--measurement--construc-
    tion and properties--resistor color
    code--resistance factors

17. WHAT A CIRCUIT IS

18. DIRECT CURRENT SERIES CIRCUITS
    definition--simple electric circuits--
    switches--circuit symbols--hand tools
    --soldering irons--connections--
    resistance in series--current flow--
    voltage--open circuits--short circuits

19. OHMS LAW
    examples in simple circuits--in
    series circuits

20. ELECTRIC POWER
    definition--units--rating of equip-
    ment fuses--series circuits

21. DIRECT CURRENT PARALLEL CIRCUITS
    connections--resistances--current
    flow--voltage--Ohm's law

22. DIRECT CURRENT SERIES--PARALLEL
    CIRCUITS
    connections--resistances--current

23. KIRCHHOFFS LAWS
    importance--1st law--2nd law

24. ELEMENTARY GENERATORS
    importance--electricity from mag-
    netism--practical generators--
construction--operation--output--
AC to DC--commutator--improving
DC output
25. ELECTROMAGNETIC FIELDS
field loop--field strength--permanent
magnets and fields
26. DIRECT CURRENT GENERATORS
construction--field windings--types of
armature windings--separately excited
DC generators--self-excited DC gener-
ators--shunt generator--compound
generator--commutation--armature
reaction--compensating windings and
interpoles
27. DIRECT CURRENT MOTORS
 electrical power converted to mechani-
cal--motor principles--commutator
action in DC motors--armature reaction
--reversing motor rotation--counter
EMF--changing motor speed--shunt
motors--series motors--compound
motors--comparison
28. DC MOTOR STARTERS
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  2 and 3 point starters--series motor
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29. DC MACHINERY MAINTENANCE AND
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  and brushes--insulation breakdown--
megger--field coils
30. WHAT ALTERNATING CURRENT IS
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sine waves--cycles--frequency--
peak to peak value--average value--
effective value--AC power transmission--
AC voltmeter--voltage wave forms--
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31. AC METERS
  rectifier type volt meters--moving-
vane meter movements--hot-wire
  and thermocoupled meters--electro-
dynamometer--AC ammeter
32. RESISTANCE IN AC CIRCUITS
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33. INDUCTANCE IN AC CIRCUITS
  definition--influencing factors--
  units--time constant--reactance--
  counter EMF--current flow--phase
  angle
34. POWER IN INDUCTIVE CIRCUITS
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tive power--apparent and true power--
measurement of true power
35. CAPACITANCE IN AC CIRCUITS
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36. CAPACITORS AND CAPACITIVE
REACTANCE
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in series and parallel--types--color
  code--time constant--reactance--
construction and marking--RC time
  constant
37. IMPEDANCE IN AC SERIES CIRCUITS
  circuit combinations--definition
  --Ohm's law
38. CURRENT VOLTAGE AND RESONANCE
IN AC SERIES CIRCUITS
39. ALTERNATING CURRENT PARALLEL
CIRCUITS
  voltage--currents--R and L--
  L and C
40. RESONANCE IN AC PARALLEL CIRCUITS
41. ALTERNATING CURRENT SERIES--
PARALLEL CIRCUITS
42. TRANSFORMERS
APPENDIX B

Standard Work Form
STANDARD WORK FORM

Specification
1. Title: Halfwave rectifiers - Dry metal
2. Complete the drawing on back side
3. List parts needed.

Instructor's Check

terminal strip
wire holder
fuse, 15 amp
releasable rectifier
SPST switch
2K 20W resistor
wire connectors
lead wire
solder

1. $R_1 + C = 20 \mu \text{F}$
2. $R_2 + C = 64 \Omega$
3. $V_1 + R_3 = 11.4$V
4. $R_4$ - Linear = 2000 ohms
5. $R_5$ - Rev. = 66 K ohms
6. $R_6$, $\text{H}+$ Chasis = 
7. $R_7$, " = 0
8. $R_8$, " = 0
9. $V_9$, $A + C = 60$V
10. $V_10$, $C + B = 55$V
11. $I_1 = 36$mA

4. Make the schematic drawing for recording the results of your work, and list all values on the parts.

Hook-up Check

Schematic Check

Hold -

Computation Check
APPENDIX C

Work Chart
APPENDIX D

Zbar Instructor's Guide
List of Experiments

Experiment

1  Electronic Components and Their Symbols
2  The Schematic Diagram
3  Familiarization with Hand Tools Used in Electronics
4  Soldering Techniques
5  VTVM Familiarization
6  Resistor Color Code and Use of Ohmmeter
7  Dry Cells and Measurement of D-C Voltage
8  Direct-current Measurement and Control of Current
9  Ohm's Law
10 The Series Circuit
11 Characteristics of a Parallel Circuit
12 Characteristics of Series-parallel Circuits
13 Kirchoff's Laws (for One Generator)
14 Voltage-divider Circuits (Unloaded)
15 Voltage-divider Circuits (Loaded)
16 Defect Analysis of Voltage, Current and Resistance Measurement
17 Nonlinear Resistors--Thermistors
18 Nonlinear Resistors--Variators
19 Characteristics of a D-C Motor Movement
20 Voltmeter Multipliers
21 Current-meter Shunts
22 The Series Ohmmeter
23 Design of a Volt-Ohm Milliammeter
24 Use and Care of the VOM
25 Balanced-bridge Circuit
26 Thevenin's Theorem
27 Norton's Theorem
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<tr>
<td>28</td>
<td>Maximum Power Transfer</td>
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<td>29</td>
<td>Oscilloscope Operation</td>
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<td>30</td>
<td>Oscilloscope Voltage Calibration</td>
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<td>31</td>
<td>Lissajous Patterns</td>
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<td>32</td>
<td>Characteristics of an Inductance</td>
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<td>33</td>
<td>Inductances in Series and in Parallel</td>
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<td>34</td>
<td>Capacitor Color Code and Testing Capacitors</td>
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<td>35</td>
<td>RC Time Constants</td>
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<td>36</td>
<td>Characteristics of a Capacitor</td>
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<tr>
<td>37</td>
<td>Total Capacitance of Capacitors in Series and in Parallel: the Capacitive Voltage Divider</td>
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<td>Impedance of a Series RL Circuit</td>
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<td>39</td>
<td>Characteristics of a Series RL Circuit</td>
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<td>Impedance of a Series RC Circuit</td>
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<td>41</td>
<td>Characteristics of a Series RC Circuit</td>
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<td>42</td>
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<td>43</td>
<td>Characteristics of a Series RLC Circuit</td>
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<td>44</td>
<td>Characteristics of Series-resonant Circuits</td>
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<td>Impedance of a Parallel RL and of a Parallel RC Circuit</td>
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<td>Characteristics of Parallel-resonant Circuits</td>
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<td>Transformer Characteristics</td>
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<td>Phase-shifting Networks</td>
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</table>
APPENDIX E

Instructor's Guide and Laboratory Manual
for
Experimental Course
THE INSTRUCTORS GUIDE
FOR
TEACHING BASIC ELECTRICITY

This guide has been prepared with emphasis on the practical approach to teaching the construction, operation, adjustment and theory of basic electricity circuits. Students will learn their skills by doing.

Discussion of theory must be related to practical circuit work to be meaningful. While intricate design theory may be interesting to the teacher, students are primarily interested in circuit concept and its practical application. The student must concentrate on learning what he NEEDS to know. Any activity that does not contribute directly to building the necessary concepts is wasted effort, regardless of how interesting it seems to be.

The student must understand the teaching goals for each demonstration. The objectives or goals are stated in the students laboratory manual, but the mere statement is not enough. The teacher must be certain that the student understands the objectives so that he will know when he has reached them. The demonstration will have been completed when the student has attained the concept to the best of his ability.

Study assignments should be tied directly to the work to be discussed the following day. Circuit diagrams and material to be discussed the following day should be given out at the end of the previous day.

It is the teachers responsibility to guide any discussions to accomplish learning goals. The frequent use of actual equipment and training aids will help. When a skill is to be acquired--talk should be minimized and actual work on the equipment should proceed. Frequent teacher demonstration of the correct techniques followed by students doing will speed learning.
The students laboratory manual is intended for his retention at the end of this course. Blank pages have been provided for note taking which should be encouraged.

This is a beginning course in electricity. Therefore, it is advisable to provide detailed procedural directions. It is true that it would be beneficial to the student if he could be turned loose in the lab with the necessary equipment and be required to proceed largely on his own. This is not practical however, because of the danger to equipment and loss of valuable lab time. By comparison, it has been established that carefully following the detailed form specified by this lab manual is best.

The care of test equipment should be clearly defined by the teacher. Carelessness will result in damaged equipment leading to loss of time and money. It is a good practice for students to have circuits checked by the instructor before the power is turned on.

Volt meters (Figure 1) must be connected in parallel and the scale must be at least ten percent higher than the highest voltage to be measured. If a scale change switch is used it should be started on the highest voltage position.

Milliameters (Figure 2) are to be used in series and a fuse rated at the same value as the meter will be a good policy.
A shorting jumper (Figure 3) will take the load off the movement when the meter is not in use.

An Ohmmeter (Figure 4) should never be used on a circuit that has a voltage source such as a battery, unless the source is disconnected. If the meter has a scale change switch, it should be on the high voltage position so as to protect the ohmmeter battery.
The use of meters should be a lesson by itself and time spent with the students in practice with a large mock up or projection will be time well spent.

A great deal of valuable time may be lost in the "building" of circuits. While it is true that "building centered" programs keep students busy, such programs will not help students acquire the understanding and skills they need or make them employable. Therefore, a "building centered" program is doomed to fail before it starts. There are many commercial bread boarding (Figure 5) devices which may solve the "time" problem.

Simple or complex circuits may be built quickly and can be easily studied in the laboratory. Parts can be changed and the effect on circuit operation noted quickly and easily. The component parts can be used over and over again. Money as well as time are saved. Low cost units (Figure 6) such as masonite on wooden frame, using 6-32 x 1/2 nut and bolt connectors will do the job.
INTRODUCTION TO ELECTRIC CIRCUITS

The beginning student of the science of electricity often feels that there is something mysterious about electric circuits. This is far from true. There is nothing about this science, when approached in an organized manner, that is too difficult for the average person to understand.

The following three approaches of study will be combined in this course: general information from the text; specific information from the Lab manual; and laboratory experiences from the experiments. Of these, the lab experiments are most important, since it is when the circuits are actually built that the major characteristics of circuits become easily apparent.

I. Description of Circuits. Webster says a circuit is the "act of moving or revolving around as in a circle or orbit; a circuitous path or journey." Therefore a normal electrical circuit is the movement of electricity in a circle. The three major problems the student will have with the circuits are classified as follows-- the "short" conditions, the "open" condition, and the "intermittent" condition. A "shorted" circuit is one that has a path from and back to the source of power that is shorter than intended in the original design. This condition is easily recognized by (1) a great amount of current flowing, (2) a drop in voltage at the source when the switch is closed, or (3) almost no resistance. The "open" circuit means that there is no continuity, that is, no complete path for the electrons to follow. This may be recognized by (1) voltage at the source which is unchanged when the switch is closed, (2) no current flow, and (3) resistance which is indicated by a reading of "infinity" (Figure 7) on an ohmmeter. The "Intermittent" is one of these two conditions on a part time basis and can usually be found at a point of connection. So much for the
Next the student will need a bit of actual experience. It is expected that the novice will experience the above circuit difficulties often. Only by troubleshooting will the student learn the fundamentals.

II. Electrical Symbols. It is good procedure to become familiar with electrical symbols at this point. Diagrams of electrical circuits use symbols to indicate circuit components and equipment. The chart on page ___ gives a list of conventional symbols used in electrical circuit diagrams in the laboratory manual.

III. Building a Circuit. The first experiment will be to build a complete electric circuit. This will be a path through which electrons can flow. It consists of a source of electrical pressure (battery or transformer), a conductor (wire), which carries the current, a control (switch) to start and stop the flow of electricity, and an electrical device (lamp) in which the electrical energy is used or converted to light and heat energy.
IV. Structures for Circuitry. Structures for circuitry vary from a schematic glued to a piece of cardboard with the components soldered together to special "experimenters chasses" which provide for quick mock-ups and re-use of expensive parts. For example, the main wiring deck (Figure 8) may consist of a sheet of phenolic 3/32" thick having a uniform pattern of punched holes. The deck is mounted on a rectangular wood frame by means of screws through the holes at the edge of the deck.
Layout paper (Figure 9) is available for the hole pattern for preplanning the circuit.

If spring clips such as a Vector T30 (Figure 10) are used, they should be pushed into holes in the deck at component or wire junction with a P92 Insertion Tool (Figure 10).

To insert wires simply press the washer on the top down with the thumb and forefinger. This exposes the slot in the main body of the terminal which can accommodate as many as six wires of average size. Wires may also be wrapped around the post between spring coils. One of the greatest advantages of pressure connections is the avoidance of messy, time consuming unsoldering to salvage components.

The heavy parts such as chokes and transformers may be fastened to the deck with 4/40 x 1/2" screws and nuts and spade lugs (Figure 11).
A potentiometer may be mounted with an L shaped metal bracket or a Vector B20 bracket (Figure 12). Punched metal strips may be used as a common tie where many connections are needed. The Vector T57 (Figure 13) or a strip of 1/2 x .20 copper will work equally well. When all parts are mounted and all wires are run, a check should be made to determine resistance before power is supplied.
V. Measuring Circuit Electricity. A Voltage, which is electrical pressure, is measured in units called volts. When a circuit has been constructed and we wish to measure its exact voltage we will use a device called a voltmeter. When electromotive force (voltage) is measured, connect the two leads (wires) of the voltmeter (Figure 14) across the unit to be measured. A DC device such as a battery has positive (+) and negative (-) polarity and the voltmeter should always be connected positive meter terminal to positive battery terminal and negative meter terminal to negative battery terminal. No need to worry about this with AC voltage as no polarity of importance is present and either wire of the voltmeter is the same.
B. **Current**, the movement of electrons, is measured in units called amperes. Current is easy to measure and all the student need do is to connect the ammeter (Figure 15) into the path of the current and observe that the positive terminal is connected to the positive in regard to the battery, and the negative to the negative. With AC no polarity need be observed.

C. **Resistance** is the opposition to the flow of current. The unit is called the ohm and the measuring instrument is called the ohmmeter. The ohmmeter is used with one lead (wire) connected to each end of what is being measured. No polarity is present. The major rule to remember is that the ohmmeter has its own power and should never be used in a live circuit.

VI. **Conclusion:**
DEMONSTRATION OF SERIES CIRCUITS

Objective:
To see the effect of series-connected resistances on voltage and current.

Supplies:
1. Five 1-1/2 Volt Dry Cells
2. 0-10 Volt Meter
3. 0-1 Amp Ammeter
4. Three Miniature Lamp Sockets
5. Three No. 41 Lamps
6. Three No. 605 Lamps
7. S.P.S.T. Switch
8. Ohmmeter
9. 64AA32 Phenolic Vectorboard
10. X64AA32-1 Wood Frame Members
11. B20 Potentiometer--Switch Bracket
12. Ground Buss Strap
13. 4 - 40 x 5/16 Self Taps
14. P92 B Tool, Spring Depressing
15. P92 A Tool, For Insertion of T30
16. 24 - T30N Solderless Terminals
17. Fuse Mount
18. 1 Amp Fuse
19. Five Vector Battery Mounts

Procedure:
1. Connect three lamp sockets in series and insert 2-volt lamps in the sockets.
2. Use the ohmmeter to measure the resistance of each lamp.
3. Measure the resistance of the three lamps in series.
4. Connect a volt meter across the battery and make sure that it reads 6 volts.
5. Connect the ammeter in series with the negative lead of the battery to the negative lead of the ammeter.

6. Connect the lamp in series from the positive lead of the ammeter to the positive lead of the battery.

7. Place 6-volt lamps in the sockets after removing the 2-volt lamps. Note the ammeter reading 0.120 A.

8. Replace one of the 6-volt lamps with a 2.5-volt lamp of less resistance. Note the ammeter reading 0.150 A.

9. Replace another of the 6-volt lamps with another 2.5-volt lamp of less resistance. Note the ammeter reading 0.202 A.
10. Replace the last 6-volt lamp with a 2.5-volt lamp. Note the ammeter reading \(0.420 \, A\).

11. Remove one cell of the battery and note voltage at each bulb and ammeter reading \(0.360 \, A\).

12. Add two cells to the battery to replace the one removed. Note the ammeter reading \(0.465 \, A\).

13. Loosen one of the lamps and note the result \( \text{No I} \).
14. Using an ohmmeter place the leads on each lamp to find the loose bulb.

15. Place a lamp in a socket and attach two wires to the socket.
16. Strip the insulation from a piece of wire 6" long. Touch each end to the lamp base connections. Note the results: end lights operate, test lamp operates

17. Note the ammeter reading when the base of the loose bulb is shorted with the wire .560A. Compare this ammeter reading with the ammeter reading you obtain when you short a good bulb 0.0 A.
18. With the wire still shorting a bulb take an ohmmeter reading at that bulb. Compare with reading from unshorted bulb.

19. Place a test lamp across the terminals of each lamp of the circuit. Note the difference in the test lamp when it is across the shorted lamp it doesn't light.
APPENDIX F

Adjunctive Programming Questions

(Auto Clue)
WHAT ELECTRICITY IS

1. The smallest particle of any specific type of matter that retains the chemical characteristics of that matter is known as the:
   (a) electron (c) molecule
   (b) proton (d) neutron

2. The smallest particle of water is composed of:
   (a) 12 electrons, 3 protons (c) 12 electrons, 3 neutrons
   (b) 1 oxygen atom, 2 hydrogen atoms (d) 2 oxygen atoms, 2 hydrogen atoms

3. In an atom the positively-charged particles are known as:
   (a) protons (c) electrons
   (b) neutrons (d) free electrons

4. As we understand it, an electric current is the motion of:
   (a) molecules (c) neutrons
   (b) protons (d) electrons

HOW ELECTRICITY IS PRODUCED

5. An object that is positively charged has:
   (a) an excess of protons (c) a shortage of electrons
   (b) an excess of neutrons (d) a shortage of molecules

HOW FRICTION PRODUCES ELECTRICITY

6. When a hard-rubber rod is rubbed with fur, the resulting electrical charges are:
   (a) rod negative, fur positive (c) both rod & fur positive
   (b) rod positive, fur negative (d) no electrical charge results

7. Experiments with static electricity prove that:
   (a) unlike charges attract (c) like charges attract
   (b) unlike charges repel (d) no effects are detectable

8. To use the contact method of giving a metal bar a positive charge:
   (a) rub it with fur (c) rub it with silk
   (b) touch it with a positively-charged rod (d) touch it with a negatively-charged rod

9. To use the induction method of giving a metal bar a positive charge:
   (a) rub it with fur (c) touch it with a positively-charged rod
   (b) touch it with a negatively-charged rod & a finger (d) touch it with a finger while almost touching it with a negatively-charged rod
Directions: Erase in the rectangle where you think the correct answer is. Preferably use an ink or typewriter eraser or a clean pencil eraser, which is firm and abrasive, and has a reasonably sharp edge. "T" means "right," any other alphabetical response - E, H, or L - means "wrong." However, your instructor may choose to designate responses other than "T" as the correct answer responses for a particular exercise. If you uncover other than the response designated as correct, and the instructor wishes you to learn the correct answer, continue erasing until that response is revealed, erase as little as possible.
APPENDIX G

Bell Laboratories Electricity Examination
1. Like charges _______________ each other.

2. When a balanced atom loses electrons it becomes a _______________ ion.

3. Both positive and negative charges are produced by the movement of _______________.

4. Objects containing more positive ions than negative ions have a _______________ charge.

5. When a negatively charged rod contacts an uncharged bar, a _______________ charge is produced in the bar.

6. A material with negative ____________ (use symbol) has an excess of electrons.

7. If two objects both have an excess of electrons and are brought together, electrons will flow to the object with the _______________ negative charge.

8. If a material lacks one coulomb of electrons, it has a _______________ charge.

9. Electrons always flow towards the more _______________ charge.

10. Air and rubber ionize _______________ easily than copper and silver.

11. I is measured in _______________.

12. One coulomb of – charge consists of _______________ electrons.

13. If 30 coulombs move past a point in 2 seconds $I = ( )$ _______________.

14. The device used to measure current is called an _______________.

15. State the following number using a power of ten.
   
   $458,000,000 = 4.58 \times$ _______________.

16. Which way will the electrons flow when two objects with unequal charges are brought into contact?

17. An uncharged rod touches a positive charged bar. _______________ will move from the _______________ to the _______________.

18. An aluminum atom has 13 protons. To remain a balanced atom, it must have exactly _______ electrons. The total charge is _______________. If there are more protons than electrons, the charge is _______________.

19. A positively charged object, $A$, is brought close to, but not touched.
APPENDIX H

Tests for Skewness and Kurtosis
APPENDIX H

Test for skewness

Sum of squares = 3571.78
Sum of cubes = 6058.75

\[ m_2 = \frac{3571.78}{65} = 54.95 \]

\[ m_3 = \frac{6058.75}{65} = 93.21 \]

\[ g_1 = \frac{m_3}{m_2 \sqrt{m_2}} = .20 \]

Test for kurtosis

\[ b_2 = \frac{m_4}{(m_2)^2} = \frac{643,085.75/65}{(54.95)^2} = \frac{9,878.27}{3019.50} = 3.2 \]
Table for Testing Skewness

(One-tailed percentage points of the distribution of $\sqrt{b_1} = g_1 = m_3/m_2^{3/2}$)

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<th>Percentage Points</th>
<th>Standard Deviation</th>
<th>Size of Sample</th>
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*Since the distribution of $\sqrt{b_1}$ is symmetrical about zero, the percentage points represent 10% and 2% two-tailed values. Reproduced from Table 34 B of Tables for Statisticians and Biometricians, Vol. 1, by permission of Dr. E. S. Pearson and the Biometrika Trustees.

Table for Testing Kurtosis

(Percentage points of the distribution of $b_2 = m_4/m_2^2$)

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<td>3.37</td>
<td>2.67</td>
</tr>
<tr>
<td>550</td>
<td>3.57</td>
<td>3.35</td>
<td>2.69</td>
</tr>
<tr>
<td>600</td>
<td>3.54</td>
<td>3.34</td>
<td>2.70</td>
</tr>
</tbody>
</table>

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APPENDIX I

Weekly Feed-Back Quizzes for Experimental Course
Instructions: These are multiple choice questions. Each question has only one correct answer. Place an x on the line that you think correctly completes the statement.

1. It is assumed that the atom is made of particles of electricity. These particles are:
   ____ (a) protons and electrons.
   ____ (b) copper and carbon.
   ____ (c) photons and protons.
   ____ (d) electrons and photons.

2. The particles of electricity revolving around the nucleus of the atom are called:
   ____ (a) protons.
   ____ (b) neutrons.
   ____ (c) photons.
   ____ (d) electrons.

3. If a normal (uncharged) atom contains a total of 19 units of positive charge, the number of units of negative charge it would contain is:
   ____ (a) 38.
   ____ (b) 57.
   ____ (c) 8.
   ____ (d) 19.

4. If an atom loses one of its negative charges the atom:
   ____ (a) is negatively charged.
   ____ (b) is positively charged.
   ____ (c) is neutral.
   ____ (d) becomes stable.
5. The sentence that is not correct states that:
   (a) Positive charges repel one another.
   (b) Negative charges repel one another.
   (c) Unlike charges repel one another.
   (d) Unlike charges attract one another.

6. Free electrons are normally liberated from:
   (a) inner orbits of atoms of gaseous elements
   (b) the nucleus of all atoms.
   (c) outer orbits of atoms of metallic elements.
   (d) the protons of metallic elements.

7. When a body is charged by any known means:
   (a) positive charges are added or removed.
   (b) negative charges are added or removed.
   (c) neutral charges are added or removed.
   (d) contact charging is always involved.

8. Excess electrons at rest in a body represent:
   (a) static electricity.
   (b) magnetic electricity.
   (c) dynamic electricity.
   (d) no electricity.

9. The method of transferring charge without the charged bodies touching is called:
   (a) contact.
   (b) friction.
   (c) molecular.
   (d) induction.

10. If a positively charged body (A) is placed close to an uncharged body (B) the side of B facing A will display:
    (a) a positive charge.
    (b) a negative charge.
    (c) no charge.
    (d) a changing charge.