DOCUMENT RESUME

ED 030 735 VT 008 722

By-Finch, Curtis R.
Self-Instructional Methods of Teaching Diagnostic Problem Solving to Automotive Students. Vocational-Industrial Education Research Report.
Pennsylvania State Univ., University Park. Dept. of Vocational Education.
Spons Agency-Pennsylvania State Dept. of Public Instruction, Harrisburg.
Pub Date Jun 69
Note-114p.
EDRS Price MF-$0.50 HC-$5.80
Descriptors-Achievement Tests, Attitude Tests, Autoinstructional Methods, *Auto Mechanics, Experimental Groups, *Experimental Teaching, Performance Tests, *Problem Solving, Student Attitudes, *Teaching Methods, *Technical Education

The objective of this study was to investigate the effects of three methods of teaching diagnostic problem-solving (troubleshooting) to automotive students. The sample consisted of 45 community college students enrolled in automotive courses. Initially, all students received a presentation on ignition principles, and the Otis Mental Ability Test was administered to establish a covariate. Individuals were then assigned to treatment groups in equipment oriented instruction, textbook oriented instruction, or programed instruction. Following the treatments each student completed an attitude inventory, knowledge test, and a troubleshooting performance test. Analysis of covariance solutions indicated no significant differences existed in troubleshooting knowledge or attitude toward instruction. The equipment oriented treatment group required the shortest instructional time and its troubleshooting performance was significantly (.01 level) better than the other two groups. It was concluded that programed or text oriented methods were most effective for knowledge learning and equipment oriented methods were most effective for performance learning. Sample instructional materials and the instruments are appended. (EM)

DOCUMENT RESUME

ED 030 735 VT 008 722

By-Finch, Curtis R.

Self-Instructional Methods of Teaching Diagnostic Problem Solving to Automotive Students. Vocational-Industrial Education Research Report.

Pennsylvania State Univ., University Park. Dept. of Vocational Education.

Spons Agency-Pennsylvania State Dept. of Public Instruction, Harrisburg.

Pub Date Jun 69

Note-114p.

EDRS Price MF-$0.50 HC-$5.80

Descriptors-Achievement Tests, Attitude Tests, Autoinstructional Methods, *Auto Mechanics, Experimental Groups, *Experimental Teaching, Performance Tests, *Problem Solving, Student Attitudes, *Teaching Methods, *Technical Education

The objective of this study was to investigate the effects of three methods of teaching diagnostic problem-solving (troubleshooting) to automotive students. The sample consisted of 45 community college students enrolled in automotive courses. Initially, all students received a presentation on ignition principles, and the Otis Mental Ability Test was administered to establish a covariate. Individuals were then assigned to treatment groups in equipment oriented instruction, textbook oriented instruction, or programed instruction. Following the treatments each student completed an attitude inventory, knowledge test, and a troubleshooting performance test. Analysis of covariance solutions indicated no significant differences existed in troubleshooting knowledge or attitude toward instruction. The equipment oriented treatment group required the shortest instructional time and its troubleshooting performance was significantly (.01 level) better than the other two groups. It was concluded that programed or text oriented methods were most effective for knowledge learning and equipment oriented methods were most effective for performance learning. Sample instructional materials and the instruments are appended. (EM)

SELF-INSTRUCTIONAL METHODS OF TEACHING DIAGNOSTIC PROBLEM SOLVING TO AUTOMOTIVE STUDENTS

Curtis R. Finch

The research reported herein was partially supported by the Bureau of Vocational, Technical, and Continuing Education, Pennsylvania Department of Public Instruction

Department of Vocational Education
The Pennsylvania State University
University Park, Pennsylvania

June, 1969

ACKNOWLEDGMENTS

Gratitude is acknowledged for the encouragement and assistance provided by colleagues at the Pennsylvania State University: Dr. Seymour T. Brantner, Dr. Joseph T. Impellitteri, Dr. Donald W. Johnson, and Dr. William A. Williams. These persons who made meaningful contributions to developmental aspects of the study included Dr. David C. Bjorkquist, Dr. George L. Brandon, and Dr. John M. Shemick.

Assistance in the administration of experimental treatments by Edward D. Cory and S. R. Wiersteiner is gratefully acknowledged.

Data for the study could not have been obtained without the excellent cooperation of Dr. Kenneth E. Carl, President and Charles E. Wilkinson, Automotive Chairman at the Williamsport Area Community College. Automotive instructors at the Williamsport Area Community College who made vital contributions to the study were Delmont F. Bergey, Robert L. Follmer, William F. Haney and Marlin M. Roush.

Those persons who graciously provided facilities and students for the development of instruments used in this study included: Edward Thomas, Dean Gwin, and George Johnson, Tyrone School District; Merrill Alexander and John Alexander, Centre County Area Vocational Technical School; Robert Fike and Robert Charles, Clearfield Area High School.

Curtis R. Finch
Research Specialist
June, 1969

TABLE OF CONTENTS

TABLE OF CONTENTS CONT'D

LIST OF TABLES

ABSTRACT

The objective of this study was to investigate effects of three methods of teaching diagnostic problem solving (troubleshooting) to automotive students. Experimental comparisons were made among shop oriented, textbook oriented, and programed self-instructional methods with a different method of instruction presented to each of three student groups. Four hypotheses specified that no differences existed among the groups in (1) troubleshooting strategy knowledge, (2) troubleshooting strategy performance, (3) time taken to complete instruction, and (4) attitude toward instruction received. Three additional hypotheses stated that no relationship existed between students' (5) attitudes toward instruction received and troubleshooting strategy knowledge, (6) attitudes toward instruction received and troubleshooting strategy performance, and (7) troubleshooting strategy knowledge and troubleshooting strategy performance within each of the groups.

The sample consisted of forty-five post-high school male students enrolled in an automotive curriculum at a community college. Initially, all students received a presentation dealing with principles of the ignition system. An ignition system knowledge examination and the Otis Mental Ability Test were then administered to serve as control variables in the covariate data analysis. Students were randomly assigned to one of three treatments. The content of each treatment was similar. All students were presented with the same practice troubles to locate and used the same troubleshooting strategy. The equipment oriented instruction was conducted using operational automobile engines for each student. The programed instruction consisted of a booklet which utilized linear and intrinsic programing techniques. The textbook instruction contained content comparable to the programed instruction treatment without

reinforcement. After each student completed his instructional treatment he filled out an attitude inventory. A thirty item multiple choice troubleshooting knowledge examination was then administered. This was followed by a troubleshooting performance examination which required each student to locate three troubles placed in otherwise operational automobile engines. The troubles were different from those used in the three instructional treatments.

Single factor analysis of covariance revealed that no differences existed among treatment groups in troubleshooting knowledge or in attitude toward instruction received. A significant F-ratio ($p<.01$) favored the equipment treatment group and text group over the program group in shortest amount of time to complete instruction. Results of a two factor analysis of covariance indicated that differences existed among treatment groups with regard to the troubleshooting performance variable. An F-ratio significant at the .01 level favored the equipment group over the other two groups. Interaction between treatments and dimensions (test sub-scores) was not significant. The correlation between troubleshooting knowledge and attitude was positive and significant ($p<.05$) for the equipment group but not significant for the other two groups. Troubleshooting performance and attitude correlated negatively and significantly ($p<.01$) for the text treatment group. Equipment and program groups did not attain significant correlations with regard to these variables. The correlation between troubleshooting knowledge and troubleshooting performance was positive and significant ($p<.05$) for the program group but not significant for other groups.

The results suggested that it might be beneficial to use programed or text instruction of the type utilized in the study as substitutes for equipment instruction if troubleshooting knowledge outcomes are desired. If troubleshooting performance outcomes are specified, instruction on actual equipment would be more meaningful. It appeared that differences in instructional time were based upon whether or not the student received written feedback. The lack of significant differences with regard to the attitude variable suggested that variations in instructional method do not necessarily affect student attitude. There was some evidence that relationships between attitude and behavior were dependent upon the particular instructional method used. It was also found that programed instruction as specified in the study would assist students in developing relatively equal degrees of troubleshooting knowledge and performance capabilities.

I

INTRODUCTION

Technology has had a tremendous impact upon our nation. The changes which it has brought about are many. It has proven to be a stepping stone to economic prosperity and a higher standard of living. As a result of technology, salaries are higher and work is conducted more efficiently (Rosenberg, 1966).

The labor market is an area where technological change is most noticeable. Some occupations have ceased to exist while others have declined in importance. New occupations have emerged and new job requirements have been added to traditional occupations. For all occupations, however, the common denominator appears to be increased complexity. As indicated by Harris (1965):

> If the technological revolution teaches us anything at all, it teaches us that jobs at all levels are more complex and sophisticated than ever before.

One field which exemplifies change toward increased occupational complexity is that of maintenance and repair. Persons entering this area must "meet higher standards of performance to maintain and repair the increasingly complex equipment coming into general use" (U. S. Department of Labor, 1968). Concurrent with the changing responsibilities of persons in the maintenance and repair field are increased demands for their services. Employment openings in this occupational area are expected to average more than 160,000 per year during the remainder of the 1960's and over the 1970's (U.S. Department of Labor, 1968).

Job performance requirements of maintenance personnel are obviously related to the specific equipment which a worker is required to maintain and repair. There are, however, certain general functions which persons in this occupation may perform. These include precision working, operating-controlling, driving-operating, manipulating, tending, feeding-off-bearing, handling, analyzing, compiling, computing, copying, and comparing (U. S. Department of Labor, 1965).

Even though the aforementioned functions may contribute significantly to a worker's competence, one of them stands out as being of utmost importance. This function encompasses the worker's involvement with equipment analysis. It is through the analysis process that equipment and system malfunctions may be located and corrected. As indicated by Bryan (1962) equipment analysis or "troubleshooting" is, by far, the most important responsibility of the maintenance technician. Worker responsibility for analysis is not confined to a few specific occupations. There is evidence to support the contention that equipment analysis is performed by workers employed in many technological areas (Schill and Arnold, 1965). Equipment analysis competence is of paramount importance to the maintenance technician. The competent worker should be able to diagnose malfunctions utilizing strategies which are most efficient (Myers, et al., 1964). He must be prepared to solve equipment problems both swiftly and accurately.

Traditionally, the responsibility for developing basic troubleshooting competence among maintenance personnel has rested with the schools. It is here that the potential maintenance specialist is, hopefully, prepared to function in the world of work. In order to develop the student's troubleshooting ability he is first exposed to equipment theory and operation as well as the use of special test equipment. This is followed by supervised practice in troubleshooting actual equipment (Bryan, 1962). Known faults are placed into the equipment and the student is required to locate them.

The typical approach to troubleshooting instruction which involves practice on actual equipment has its shortcomings. Public schools have neglected this area of instruction because school training equipment is not usually designed to teach troubleshooting. In a curriculum designed to develop maintenance skills the student works on "live" equipment similar to that which he will encounter on the job. The equipment may belong to a customer or it may be a part of the school inventory. In either case the equipment used is usually not equipped to have representative malfunctions easily inserted and removed by the instructor. Moreover, there is usually not enough equipment available to have one item for each student to work on.

The military realized the need for efficient troubleshooting instruction during the early 1950's. In order to teach troubleshooting more easily and effectively, simulators were developed that were comparable to the actual equipment but were provided with "trouble" switches to allow a more controllable situation. Studies conducted on this type of equipment indicate that it can provide troubleshooting instruction which is equal to that afforded by actual equipment in less time (Standee, et al., 1956).

Unfortunately, public education resources have not, in the past, permitted procurement of high cost equipment which can be used for one specific purpose. The instructional gap between public education and the aspiring maintenance specialist must be filled in another way. The answer to this problem may lie in the domain of programed learning. Schramm (1962) states:

> Programed instruction is, in the best sense of the word, a truly revolutionary device; but it is revolutionary not so much in itself, as in its ability to interact with certain other developments in education. This interaction has the potential of freeing schools and men from the old bondage and outworn theories and practices. But the potential is, so far, largely unrealized.

Gagné (1965) indicates that programed instruction is a very sound educational tool. He comments that "there is every reason to suppose that good self-instructional programs are highly effective, as they have many times shown to be." It has been substantiated that programing can be used as a valid approach to teaching (DeCecco, 1964). Additionally, programs are low in cost, easy to reproduce, and could be made readily available for each student.

But the question which remains unanswered is whether or not programed learning methods can be used to teach troubleshooting, and teach it effectively. Programed texts such as those developed by Schuster (1963) and Ford Motor Company (1966) indicate that possibilities exist in this area. However, these books are not designed to simulate shop instruction. Perhaps, through research with programed learning methods, an answer may be found.

Objective and Hypotheses

The primary objective of this study was to investigate the effects of three methods of teaching diagnostic problem solving (troubleshooting) to automotive students. Experimental comparisons were made among equipment oriented, textbook oriented, and programed self-instructional methods of teaching diagnostic problem solving. In order to make these comparisons, a different method of instruction was presented to each of three student groups. Specifically, the hypotheses to be tested in this study were:

1. No differences exist among the three groups in troubleshooting strategy knowledge measured by a multiple choice test as a result of the different instructional methods.

2. No differences exist among the three groups in troubleshooting strategy performance measured by a performance test as a result of the different instructional methods.

3. No differences exist among the three groups in the time taken to complete the three instructional sequences.

4. No differences exist among the three groups in regard to attitude toward instruction received.

5. No relationship exists between students' attitudes toward instruction received and troubleshooting strategy knowledge scores within each of the three groups.

6. No relationship exists between students' attitudes toward instruction received and troubleshooting strategy performance scores within each of the three groups.

7. No relationship exists between students' troubleshooting strategy knowledge scores and troubleshooting strategy performance scores within each of the three groups.

Scope of the Study

The study was based upon the following assumptions:

1. In the public schools, automotive troubleshooting abilities are typically developed through practical activity on "live" or operational equipment.

2. Programing of instruction can be effective and can result in learning.

3. Troubleshooting performance is correlated with technical knowledge (theory and operation) of similar equipment.

II

REVIEW OF RELATED RESEARCH

Introduction

The studies which follow were chosen for inclusion in this chapter because of their close relationship to the problem. In order to establish relevance, research was grouped into three major categories:

1. Studies of the use of simulation techniques in teaching diagnostic problem solving.
2. Studies using programed instruction to teach problem solving.
3. Studies investigating the diagnostic problem solving process.

A survey of research was made to locate any meaningful studies which could be placed into one of the three categories. Sources included in this search were standard references, books, periodicals, journals, dissertations, pamphlets, and unpublished research reports. In view of the quantity of troubleshooting research accomplished by the military, particular emphasis was placed in this area.

Studies of the Use of Simulation Techniques in Teaching Diagnostic Problem Solving

A report by Standee, *et al.* (1956) listed 110 studies dealing with troubleshooting. A number of the studies employed some substitute for training on actual equipment. Several were concerned with comparing troubleshooting protocols generated while working on its synthetic counterpart. In every case, experimental results appeared to justify the use of the more controllable media.

In a study by Cantor and Brown (1956), evaluations were made of two electronics troubleshooting training aids by comparing them with equipment instruction. The two aids, which were called Trainer-Tester and Punchboard-Tutor, consisted of cards which contained typical troubleshooting problems for specific equipment. The aids were designed to allow student response and reinforcement. For the three groups compared in the study, results indicated that the Trainer-Tester and Punchboard-Tutor groups were definitely superior in intellectual aspects while the Equipment-Only (control) group was superior in equipment usage.

French (1956) has reported an evaluative comparison of instruction given on a troubleshooting trainer and instruction given on actual equipment. Forty students who served as the experimental population, were divided into two groups. One group received instruction using the trainer while the other used bench mock-ups of actual equipment. Results indicated that the group which received trainer instruction showed the same gain in troubleshooting test scores as the group taught on actual equipment.

The degree to which simulator performance represents performance in an operational situation was studied by Besnard and Briggs (1956). Air Force maintenance school students were randomly assigned to two groups. One group of students performed three maintenance procedures on the E-4 fire control simulator while the other group performed the same procedures on an operational system. The procedures performed had just been taught prior to the experiment. Comparisons were made between the two groups as to (1) the average number of total errors made, (2) the average total time required to perform the test procedures, and (3) the proportion of student error on each step required by the test procedure. No significant differences were found between groups in the total number of errors made, however, the simulator group took significantly less average total time to complete the procedures. Step error comparisons indicated a high degree of correspondence between proficiency measured by the two equipments. The authors recommend that trainers with similar design features may be found useful in maintenance training on other complex electronic systems.

Bryan and Schuster (1959) compared the training effectiveness of guidance and explanations via trainer in teaching electronic troubleshooting to five groups of students (N = 115). The criterion measure consisted of ten troubleshooting problems contained in separate booklets. Results showed that achievement of the two guidance groups was significantly superior to that of the no-guidance group. The two groups that received guidance and explanations were significantly superior in achievement to the other three groups.

In a study by Cox, et al. (1965) evaluations were made of the fidelity requirements for training devices used in fixed procedure tasks. In a series of experiments, the fidelity of training devices was progressively lowered in either functional or appearance quality. Conclusions reached were that "men trained on low fidelity devices were as proficient as those trained with devices high in functional and appearance fidelity."

Summary

The review of research dealing with simulation techniques in teaching diagnostic problem solving reveals that:

1. The use of simulators to teach diagnostic problem solving can be as effective as the use of regular equipment (Standee, et al., 1956; French, 1956).

2. Actual troubleshooting situations can be successfully simulated by artificial means (Bernard and Briggs, 1956; Cox, et al., 1965).

3. Instructional aids which promote the learning of troubleshooting knowledge may not necessarily increase the student's ability to solve actual troubleshooting problems (Cantor and Brown, 1956; Bryan and Schuster, 1959).

Studies Using Programed Instruction to Teach Problem Solving

A study by Gagné and Brown (1961) investigated the effects which variations in the programing of conceptual learning had upon performance in problem solving situations. Thirty-three 9th and 10th grade boys were assigned to three groups of 11 each and received programs involving mathematics concepts. After receiving an introductory program dealing with basic concepts, the groups each went through a different program called rule and example, guided discovery, and discovery.

Problem solving performance was measured in terms of time, number of hints required, and a weighted time score combining these factors. Performance scores indicated best performance for the guided discovery condition, discovery was next, followed by rule and example. Differences of individual means was significant at the .02 level or better.

Shettel, et al. (1961) studied the effectiveness of self-instructional techniques and materials in teaching basic job knowledges and skills to potential SAGE track monitors and intercept directors. Programing techniques applied to the two SAGE programs included an intermixture of the single response mode and program variations (branching) along with an integration of simulated console mock-ups. An analysis of field trial data indicated that personnel who received either of the training programs were equal to or more proficient than experienced personnel who took the test but did not participate in the training programs.

A major purpose of a study by Gagné and Dick (1962) was to "measure and define the nature of what is learned in a teaching machine program on solving simple algebraic equations of the first order." A teaching machine program in solving equations was administered during eight daily classroom sessions to 52 seventh grade mathematics students. After the completion of the program, students were given tests in verbal and performance achievement as well as a transfer of training test. An evaluation of data revealed that the program produced a significant amount of learning of performances involved in algebraic equation solving. The program was successful to a limited degree in the development of transfer competence to unfamiliar equations. Previous mathematics grades were found to be unrelated to scores on the transfer test of equation solving. The authors indicate that knowledge transfer appeared to be specific rather than general ability.

A report by Feurzeig, et al. (1964) describes the application of a computer system to the teaching of medical diagnosis. A computer program called the Socratic System states a problem to a student and engages him in "conversation" while he is attempting to solve the problem. A list specifying the vocabulary of the problem is given to the student before the session begins. The student's questions and declarations must be chosen from the terms on the list. Teaching strategies are specified by the instructor who prepares the problems.

Blank and Covington (1965) developed and tested a method for inducing greater amounts of question asking by children in solving problems. Fifty-four grade school students were divided into three groups for purposes of treatment. The first group received a programed instruction unit designed to induce question-asking behavior, the second group received the same program but with no training in question asking, the third group received no programed instruction. The results of criterion test evaluation indicated that pupils given the complete program asked significantly more questions on the post-tests and received higher scores on a science achievement test consisting of twenty-five general problem solving situations.

Results of a study by Anderson (1965) indicated that first grade children could acquire, retain, and transfer rather complex problem solving skills when presented with a training procedure employing programed instruction techniques. After receiving instruction in the problem solving technique of varying each factor in succession while holding all other factors constant, the trained groups was compared with a control group which did not receive the instruction. On a retention test, the trained group solved more problems with fewer unnecessary trials then the control group. The trained group also solved more transfer problems and solved these more efficiently than did the control group.

A more recent study which was conducted by Johnson (1966) compared a tutorial program with an inquiry program in teaching network analysis. Subjects, consisting of electrical engineering students, were taught by means of the PLATO Computer-based instructional system. A small sample precluded any precise comparisons. However, a significant difference did occur between the two groups with respect to achievement scores. The difference favored the tutorial group (N = 7) and appeared to occur mainly in the ability of the students to work post-test problems. An evaluation of the extent to which lesson objectives had been obtained indicated that both programs were effective in teaching electrical engineering theory course material.

Johns (1966) compared traditional and structured problem-solving methods of teaching eighth grade general science. The traditional group received lectures, observed demonstrations, and participated in laboratory activities. The experimental group were given no lectures, assignments, or textbooks. Instead, they used guide sheets which led them through activities designed to develop facts and concepts usually taught in each unit of study. Based upon the .01 level of significance, the findings revealed that there was no difference between mean scores obtained on standardized tests of problem solving, subject matter attainment, study skills, critical thinking, and attitude toward science. The traditional group performed significantly better than the experimental group on three of the five teacher-made subject matter tests.

A study by Seidel and Hunter (1968) was conducted to develop guidelines for applying programed instruction to courses that involve the learning of principles and rules used in problem solving. Experimental versions of a computer programming course were given to over 900 students in various experimental groupings. Results of a series of prompting/confirmations variations indicated that giving students extensive stimulus support during training helps motivate them and improves scores during training, but hampers them in using what they have learned. Additionally, it was found that working with a variety of practice problems facilitated the learning of problem solving skills.

Summary

Research on the use of programed instruction to teach problem solving indicates that:

1. Certain aspects of problem solving can be taught successfully with programed instruction (Shettel, *et al.*, 1961; Gagné and Dick, 1962; Feurzeig, *et al.*, 1964; Blank and Covington, 1965; Anderson, 1965; Johns, 1966).

2. Reinforcement principles utilized in programed instruction can help the student to learn problem solving (Gagné and Brown, 1961; Johnson, 1966; Seidel and Hunter, 1968).

Studies Investigating the Diagnostic Problem Solving Process

An experiment by Fattu and Mech (1953) tested the hypothesis that ability to troubleshoot or locate defects in a specified piece of equipment requires something more than being trained in the parts of components of that equipment. Fifty-four undergraduate students received identical instruction in the standard operating procedure of a gear-train apparatus after which each subject was given six problems to locate in the equipment. After the initial measure, one group received no further instruction, another group received a tape recorded basic knowledge lecture, and a third received a basic knowledge lecture plus a system analysis lecture. Post-test gains indicated that the additional troubleshooting lecture acted to produce a significant gain in malfunctions correctly located. Results also suggested that time is a dubious criterion of troubleshooting performance.

The patterns of troubleshooting behavior were analyzed in a study by Glaser and Phillips (1954). The performance of 29 guided missile trainees was studied as they each diagnosed 13 problems in a system troubleshooting board. The most outstanding pattern of failure was a faulty inference sequence in which correct check procedures were chosen but the inference from the procedures to the selection of a solution was incorrect. The authors stated that increased emphasis in training on the inferring process from check to diagnosis might contribute to the improvement of troubleshooting efficiency.

Moore, et al. (1955) studied the effects which a preplanning technique had on the improvement of generator system troubleshooting.

One hundred and forty-five airmen were randomly assigned to preplanning and control groups and were tested in ability to troubleshoot three malfunctions. The preplanning group was asked to list possible causes, outline crucial checks, and to use the outline while troubleshooting each problem. The control group was free to use any technique desired to locate the malfunctions. The preplanning troubleshooters were more successful at locating the malfunctions. The successful preplanners made fewer equipment checks, required less time, and were less likely to make systematic and repetitive errors than were successful persons in the control group.

Highland, et al. (1956) investigated the knowledges associated with successful troubleshooting on electronics equipment. Three hundred and sixty experienced radar mechanics were administered three written tests covering electronics fundamentals, knowledge and functioning of an oscilloscope, and basic reasoning ability. Each mechanic also attempted to locate six predetermined malfunctions in a simple piece of electronics equipment. An analysis of the test data revealed that technical knowledge was associated in an important way with success in troubleshooting while basic reasoning ability was not.

Bryan, et al. (1956) presented a behavioral analysis of electronics troubleshooting procedures accomplished by 81 experienced Navy technicians. Protocol data was obtained from records of trained observers, job sample troubleshooting tests, and critical behavior troubleshooting tests. Based upon data evaluation, sixty-two statements were developed which formed a behavioral framework for troubleshooting. The authors state that "some methods and results of laboratory problem solving research can be identified in the corrective maintenance situation. The same general models apply, and concepts such as set, flexibility, transfer from one problem to another, and task restructuring are common and useful to both fields."

A study by Thomas, et al. (1956) describes the development of a classification of practical problem solving situations in terms of the abilities required for solving them. The authors postulated that "maintenance problems can be conveniently classified in terms of the degree to which the difficulty of arriving at a solution is a product of inhibitory sets and the degree to which it is a product of complexity." Mechanical and electrical tasks were constructed in the two troubleshooting categories under consideration and tests were administered to 253 airmen. The results indicated that ability to solve the complex problems was related to intellectual ability and ability to solve inhibitory set problems was related to rigidity. It was also shown that the degree to which a problem elicits inhibitory sets can be controlled in part by varying the preceding conditions.

Briggs and Besnard (1956) studied the effects of differing amounts of reinforced practice upon performance in electronic system maintenance. Two groups of Air Force students (N = 36) were trained in fire control system maintenance. In the experimental group, a training device was combined with instructor techniques to achieve a greater amount of reinforced practice. In the control group, the same instructor techniques were used but for less time each day and without the training device. The experimental group scored higher than the control group on performance tests involving checks and adjustments of equipment. In both groups there was a highly significant effect of aptitude level upon performance scores.

An Air Force training study by Ray (1957) compared verbal with manipulative approaches to solving equipment problems. It was to be determined whether subjects would solve problems in a different way if they were forced to talk about them and presumably to think about the problems before proceeding. Sixty-four airmen solved an equipment problem which resembled a search for a malfunction. Another group of 64 solved the same problem but only after the subjects told what they would do before they actually touched the apparatus. The subjects in the verbal group made fewer repetitive errors and required fewer trials than did the purely manipulative problem solvers.

A study by Goldbeck, et al. (1957) investigated applications of the half-split technique of locating trouble sources in malfunctioning equipment. Experiments were conducted to study the effects of differing complexity of system and differing instructions on efficiency in locating trouble sources. Results indicated that "where the system relationships were easily mastered by a given subject, the half-split method was an aid to efficiency. However, a subject needed either relatively high ability or instructional aid to overcome the load put on his capacities by the more complex systems." The authors conclude that deductive ability is a prerequisite for application of the half-split technique to a troubleshooting task.

Stolurow, et al. (1957) studied the effect which different amounts, types, and sequences of training and experience had upon ability to recall information required in the solution of two types of maintenance problems. Subjects were divided into groups which were alike in several critical respects, with every group different from each of the other groups in at least one respect such as amount of job experience or formal training on the R-4360 engine. All subjects were given two sets of problems. One set of problems gave statements of symptoms for which they were required to recall all the possible causes while another set of problems gave causes of malfunction for which they were required to recall all the symptoms. The authors stated the following conclusions based upon an evaluation of data:

1. Learning associations in one direction do not mean they are equally well learned in the reverse direction.
2. Persons with the opportunity to learn symptom-to-cause associations (for brief periods) showed relatively poorer performance on problems requiring associations in the reverse direction than persons who had no opportunity to learn.
3. When the opportunity to learn is longer, performance is better on the problems requiring association in the reverse direction.

Experiments by Dale (1958) were concerned with how persons troubleshoot without special training. Laboratory conditions were used with observations and recordings made of the subjects who attempted to find faults in specially constructed electronic equipment. The author found that (1) in a complex flow problem naive subjects did not use what was theoretically the best strategy of searching, (2) subjects improved their strategies when they were given a series of problems,

(3) the logical requirements of a task do not determine the strategy which men will use, (4) subjects who adopted appropriate strategies were significantly more intelligent than those who did not.

Miller and Slebodnick (1958) used laboratory controlled situations to test the amounts of transfer resulting from training content and procedures directed toward different types of maintenance skills. The major purpose of the study was to test the degree of transfer resulting from initial general training in troubleshooting principles and to measure the self-induction of principles by students who received general training only in concepts of data flow. Experimental comparisons of treatment groups consisting of male high school students indicated that a troubleshooting strategy can be taught as a set of principles and practiced with abstract materials so as to generalize to specific situations. It was also concluded that "unless correct decisions within a strategy are directly and extensively reinforced in practice, portions of the technique will be degraded by performance variables."

Generalized electronic troubleshooting training was evaluated by Warren, et al. (1958). Ninety male high school students were divided into three equal groups and received identical troubleshooting training except for the number of practice problems which the subjects solved. Analyses of ability and performance test data indicated that "systematic training in troubleshooting techniques developed skill in the application of intellectual processes to solution of abstract troubleshooting problems." The authors also indicated that generalized training decreased tendencies to make redundant actions and arrive at incorrect conclusions.

Myers, et al. (1964) logically and experimentally evaluated the various troubleshooting strategies currently in use to determine which were best suited to be taught to individuals with limited maintenance experience. On the basis of training feasibility, applicability to instruction and transfer potential, it appeared that the signal tracing, bracketing, and half-split strategies were best suited for initial training in troubleshooting. An experimental evaluation of the three strategies revealed that half-split and bracketing are superior to signal tracing since they require less time and fewer number of checks to locate troubles. The comparison of half-split with bracketing revealed neither to be superior.

Summary

Investigations of the diagnostic problem solving process disclose the following:

1. In many respects problem solving and troubleshooting are similar, however, they cannot be treated as one and the same (Bryan, et al., 1956; Thomas, et al., 1956).

2. Success in diagnostic problem solving is related to specific technical knowledge and aptitude (Highland, et al., 1956; Thomas, et al., 1956; Briggs and Besnard, 1956; Goldbeck, et al., 1957; Dale, 1958).

3. Time is a questionable criterion of troubleshooting performance (Fattu and Mech, 1953).

4. The development of a proper strategy is important to success in diagnostic problem solving (Fattu and Mech, 1963; Glaser and Phillips, 1954; Goldbeck, *et al.*, 1957; Dale, 1958; Miller and Slebodnick, 1958; Myers, *et al.*, 1964).

5. Diagnostic problem solving is best taught by means of reinforced practice (Moore, *et al.*, 1955; Briggs and Besnard, 1956; Ray, 1957; Stolurow, *et al.*, 1957; Dale, 1958; Miller and Slebodnick, 1958; Warren, *et al.*, 1958).

III

PROCEDURE OF THE INVESTIGATION

This chapter describes the procedures that were used to obtain data for the study. Explanations are given of activities which preceded the main study as well as conduct of the main study itself.

Experimental Design

The study was based upon the post-test only control group design specified by Campbell and Stanley (1963). This design is indicated as follows:

R	X_1	0_1
R	X_2	0_2
R	X_3	0_3

The design schema specifies that subjects are randomly assigned (R) to three separate treatment groups and are exposed to different experimental variables (X_1, X_2, X_3) in each of the treatments. At the conclusion of instruction, common post-tests (0) are administered to each of the treatment groups. In this study, X_1, X_2, and X_3 constitute the shop oriented, textbook oriented, and programed self-instruction treatments. The common post-measures included performance, knowledge, attitude, and time to complete instruction.

In order to make a more precise analysis among treatments, two additional tests were administered which served as control variables in the covariate analysis of data. Based upon research by Highland, et al. (1956) and Thomas, et al. (1956) cited in Chapter 2, it was felt that a system knowledge examination and a mental ability test would serve best in this capacity. These investigations indicated that specific technical knowledge and aptitude are closely related to success in troubleshooting.

An important aspect of design implementation involved the conduct of a pilot study. The purpose of the pilot investigation was to identify possible factors in the experimental design which might be detrimental to internal and external validity of the main study. Although the experimental design basically controlled for sources of invalidity (Campbell and Stanley, 1963, p. 8), it was felt that close examination should be made of instrumentation and reactive effects to experimental arrangements. These factors were chosen for investigation because of the unique evaluation and instructional procedures employed in the study.

Subjects used in the pilot study consisted of eight high school sophomores and juniors enrolled in vocational auto mechanics. Procedures employed were the same as those projected for use in the main study and fell in the general categories of pre-treatment instruction administration, pre-treatment examination, randomization, treatment administration, and post-treatment evaluation.

Based upon pilot study observations, modifications were made to the performance instrument. Additionally, provision was made for alternate equipment availability in the event of original equipment failure. In this way, students would not be affected if equipment breakdown should occur. Students appeared to react normally to the experimental treatments. It was felt, however, that all students should receive their respective treatments in the environment (classroom or shop) where they regularly received instruction so that the results would apply to a realistic school setting. With the aforementioned modifications, it was felt that the design would adequately control for possible sources of invalidity.

Statistical Tests Employed

The first general statistical hypothesis to be tested was

$$Ho: \mu_1 = \mu_2 = \mu_3 = \mu_p$$

where μ_1 is the mean criterion score of a group of students who received troubleshooting instruction via equipment, μ_2 is the mean criterion score of a group of students who received troubleshooting instruction via programed materials, μ_3 is the mean criterion score of a group of students who received troubleshooting instruction via text materials, and μ_p is the mean criterion score of students in the general population from which the sample was drawn. The criterion scores refer to four variables: troubleshooting knowledge, troubleshooting performance, time required to complete instruction, and attitude toward instruction.

The second general statistical hypothesis to be tested in this study was

$$Ho: rxy = \rho xy$$

where rxy represents each of the individual sample correlation coefficients between variables x and y for students who received troubleshooting instruction via equipment (n = 15), programed materials, (n = 15) and text materials (n = 15), and ρxy is the population correlation coefficient between variables x and y.

Within the second general hypothesis there were three specific hypotheses. These are stated

$$Ho: \ rxy = \rho xy$$

$$Ho: \ rxz = \rho xz$$

$$Ho: \ ryz = \rho yz$$

where x, y, and z consist of troubleshooting knowledge scores, troubleshooting performance scores, and attitude toward instruction.

The manner in which hypotheses concerning the treatments were tested involved the use of several statistical tests. Some of the tests were used in conjunction with more than one hypothesis. Therefore, in order to avoid repetition, these tests will be described. Data was analyzed by IBM 360/67 computer utilizing statistical programs available at The Pennsylvania State University Computation Center. A listing of the programs used in this study can be found in Appendix H.

The single factor analysis of variance was used to determine if differences existed among personal characteristics of students assigned to the three treatment groups. The analysis of variance technique determines if variations that appear among groups can be attributed to chance. It is based upon the assumption that most factors within a population which can be measured will provide a normal distribution of measurements. The statistical test capitalizes on an integral relationship between mean and variance so that, by analyzing variances, conclusions may be drawn regarding the similarity of group means (Popham, 1967).

The single factor analysis of covariance was employed in order to test hypotheses concerned with knowledge, attitude, and time variables. Analysis of covariance is a form of analysis of variance which tests the differences among criterion measure means by taking into account and adjusting initial differences in the data. Differences among experimental groups are analyzed after taking into account a pertinent independent variable or variables. The underlying rationale involves a combination of analysis of variance and regression concepts. After determining the direction and magnitude of relationship between control variables and the criterion variable, each criterion score is statistically readjusted so that compensation can be made for control variable disparity which exists between independent variables groups. The adjusted scores are then subjected to an analysis of variance (Popham, 1967).

The hypothesis regarding performance was tested by means of the two factor analysis of covariance. This test is analogous to two factor analysis of variance coupled with regression analysis. A balanced three-by-three factorial design with equal numbers in all subclasses was employed. The factors were treatments and dimensions (performance sub-scores) with the dependent variable being student performance in troubleshooting. The design is represented in Table 1.

In order to conduct a meaningful analysis of troubleshooting performance, it was necessary to give each sub-score equal weighting. Consequently, all raw scores were converted to standard scores with a mean of fifty and a standard deviation of ten prior to the statistical analysis of data.

TABLE 1

3 X 3 FACTORIAL DESIGN

Treatment	Performance Sub-Scores		
	0_1	0_2	0_3
Equipment	1,1	1,2	1,3
Program	2,1	2,2	2,3
Text	3,1	3,2	3,3

Three hypotheses involving correlation were tested. These were made using the product-moment coefficient. The hypotheses stated that the relationship between two variables would be equal to zero. Therefore, rejection of a null hypothesis required a large positive or negative coefficient (Edwards, 1964).

In order to avoid redundancy, the critical value for each of the statistical tests utilized is summarized in Table 2. A five percent (.05) critical region was chosen as the basis of rejection for each hypothesis, but statistics falling in the one percent (.01) critical regions are also reported.

Instructional Content

The instruction presented was divided into two phases. These consisted of the first or pre-experimental phase and the second or experimental phase. A detailed description of each phase is presented in this section.

TABLE 2

CRITICAL VALUES FOR STATISTICS EMPLOYED IN THE STUDY

Statistic	Degrees of Freedom	Level .05	Level .01
Analysis of Variance	2 and 42	3.23	5.18
Single Factor Analysis of Covariance	2 and 40	3.23	5.18
Two Factor Analysis of Covariance	2 and 124	3.07	4.79
Correlation	13	.514	.641

The first phase of instruction was presented to the collective student sample. This phase provided students with an opportunity to become familiarized with the ignition system. It was felt that, in order to comprehend the second phase of instruction, each student should have some exposure to system operation. This thought was based upon research cited in the previous chapter. Material used in this phase consisted of a correlated film strip and record presentation dealing with ignition system principles. The presentation had been developed by a major authomobile manufacturer for training program use and was approximately thirty minutes in length (Delco Remy).

The second phase consisted of three instructional treatments: equipment oriented, textbook oriented, and programed instruction. Content of the three treatments was similar in that each presented students with the same three troubles to locate. Additionally, a common troubleshooting strategy was taught in each of the respective treatments. In all cases, the instruction presented was individualized in nature and required each student to proceed through the treatment at his own pace.

The equipment oriented instruction was conducted using operational equipment for each student. A different trouble was placed in each of three automobile engines before the instruction began. Each student exposed to this treatment was initially given an information sheet and a troubleshooting chart (Appendix A). The information sheet introduced the instruction and explained how the troubleshooting chart was to be used. After the student had familiarized himself with these materials he was permitted to find the troubles placed in each of the three engines. The instructor assisted the student if he had questions about troubleshooting or problems with the engines.

The programed instruction consisted of a forty page booklet which utilized both linear and intrinsic programing techniques (Appendix B). By employing mixed response modes, it was felt that the program would more accurately simulate an actual troubleshooting situation. At least one study has shown that combined response programs are instructionally sound (Shettel, et al., 1961). The booklet allowed students to "find" three different troubles in each of three different hypothetical engines. These troubles were identical to those which were used in the equipment oriented instruction. Pictures were included in the booklet wherever necessary to give each student a more realistic idea of the situations he was involved with. The pictures were taken directly from shop manuals typically used in automotive instruction.

After the booklet was developed, copies were given to four high school auto mechanics students. As they proceeded through the instruction, observations were made. Based upon these observations, and interviews with the students, minor revisions were made to the instructional format.

The textbook oriented instruction also provided the student with troubles to "find." There was, however, no programing included in this treatment. Content comparable to the programed instruction treatment was developed without including any reinforcement techniques (Appendix C). The textbook was also field tested using four high school auto mechanics students. Revisions to the format were not considered necessary.

Measuring Instruments

The measuring instruments utilized in this study consisted of troubleshooting performance and knowledge examinations, an attitude inventory, an ignition system knowledge examination, and a mental ability test. In order to clarify purpose and content, a description of each instrument will be given in this section.

Troubleshooting Performance Examination

The military have, for some time, employed practical performance tests to measure troubleshooting performance and have obtained much success in this area. A report by Fattu (1956) indicates that many such tests have been developed by the military which provide an accurate measure of troubleshooting performance. Air Force (Air Training Command, 1951) and Navy (Bureau of Naval Personnel, 1952) publications are available which give detailed descriptions for performance test construction and administration.

The performance examination which was developed required the subject to locate three troubles one of which had been placed in each of three otherwise operational automobile engines. All of the troubles were representative of those studied in the second phase of instruction but were not identical. The three troubles ranged in difficulty from simple to complex, thus providing some degree of discrimination between high and low achievers.

Materials used in the performance examination administration consisted of Observer's Instructions, Student's Instructions, and a Record of Troubleshooting Behavior. These forms are presented in Appendix D. The behavior record was similar in design to the type developed by Fattu and Medley (1952). Its purpose was to record a student's sequence of actions as he attempted to find a trouble. The instrument was structured so that an examiner could accurately record observable behavior without knowing if this behavior was correct or incorrect. A separate sheet was used to record student behavior on each trouble.

Troubleshooting proficiency was based upon the following rationale:

1. The more proficient the troubleshooter, the smaller the portion of the system to which he will confine his actions for a given symptom pattern.

2. The proficient troubleshooter should extract full information from each action he performs.

3. The proficient troubleshooter should perform only those actions which contribute to obtaining the solution.

4. The proficient troubleshooter should sequence his actions so as to locate troubles with optimum efficiency.

Each completed record was analyzed to determine three troubleshooting performance sub-scores for a particular trouble. The scoring procedure is explained in Appendix D. Sub-scores consisted of information checks made, non-information checks made, and sequence followed. Thus, a student's scores reflected how closely he adhered to a predetermined optimum strategy for a particular trouble. Common subscores for each of the three troubles were added together to produce combined sub-scores. This procedure is presented graphically in Table 3.

TABLE 3

PROCEDURE USED TO OBTAIN COMBINED PERFORMANCE SUB-SCORES

Sub-Scores	Troubles						Combined Sub-Scores
	T_1		T_2		T_3		
Information checks made (I)	I_1	+	I_2	+	I_3	=	I_T
Non-information checks (N)	N_1	+	N_2	+	N_3	=	N_T
Sequence followed (S)	S_1	+	S_2	+	S_3	=	S_T

The examination was field tested using high school vocational auto mechanics students. After a trouble was placed in an engine, students were given an opportunity to see if they could locate the malfunction. As each student proceeded, two observers working independently recorded the student's behavior. Elements of the examination on which observers disagreed were revised. Based upon pilot study experiences, student instructions were revised and the scoring procedure was modified.

Troubleshooting Knowledge Examination

The examination used to determine troubleshooting knowledge consisted of questions related to the common instructional content. Since multiple choice questions can be developed which measure reasoning and problem solving, it was felt that this type of test item should be used (Educational Testing Service, 1963). Each item was constructed to provide a direct question followed by four possible answers, only one of which was correct. Item content was oriented toward specific steps in the strategy which was taught.

After the examination was developed it was reviewed by three teachers who were familiar with test construction principles and automobile maintenance. Based upon their comments, some of the items were revised or discarded. The examination was then administered to forty-three high school auto mechanics students who had just finished a lecture dealing with troubleshooting content to be taught in the study. Data analysis produced the following statistics:

Mean difficulty of items	0.534
Average item-total score correlation	0.408
Standard error of correlation	0.154
Estimated interitem correlation	0.166
Kuder-Richardson 20 reliability	0.727
Test mean	18.67
Variance	24.51
Standard deviation	4.95

An analysis of individual items revealed that five appeared questionable in the areas of difficulty and discrimination. These items were discarded. The thirty item troubleshooting examination appears in Appendix E.

Attitude Inventory

The attitude inventory used in this study was of the Likert type (Likert, 1932). The inventory consisted of forty-seven statements, each of which was followed by a five point scale ranging from strongly agree to strongly disagree (Appendix F). Based upon administration to 60 high school auto mechanics students, the instrument had a reliability of .918. It was additionally determined that the inventory had sufficient validity for intended purposes. A detailed description of instrument development is provided by Finch (1969).

Ignition System Knowledge Examination

A multiple-choice examination was developed in order to measure differences in student knowledge about the ignition system. This instrument was used as a control variable in the covariate analysis which was previously discussed. Examination items were based upon instruction presented in the first phase of the study. Three teachers reviewed the instrument and, based upon their reactions, some of the items were revised or removed. The completed examination was administered to thirty-four auto mechanics students who had just completed the first instructional phase. Data analysis revealed the following statistics:

Mean difficulty of items	0.659
Average item-total score correlation	0.506
Standard error of correlation	0.174
Estimated interitem correlation	0.256
Kuder-Richardson 20 reliability	0.747
Test mean	13.21
Variance	11.99
Standard deviation	3.46

Based upon a difficulty and discrimination analysis of individual items, one item was removed. The nineteen item ignition system knowledge examination is presented in Appendix G.

Otis Mental Ability Test

An additional control variable used in the covariate analysis was general ability. The Otis Quick-Scoring Mental Ability Test, Gamma, Form FM, was used to measure this dimension (Otis, 1954). The test was chosen for several reasons. First, it is virtually self-administering. Second, the test may be taken in a relatively short period of time. Most important, however, the Otis test has a long history of use as a valid and reliable mental ability measure.

Procedure

The conduct of the study is explained in this section. Descriptions are given of the sample used and data collection procedures performed.

Sample

The sample utilized in the study consisted of forty-five post-high school male students enrolled in an automotive curriculum at the Williamsport Area Community College. The group, which was comprised of first and second year students, had a mean age of nineteen years, five months. The student sample had a mean of 48.089 with a standard deviation of 9.865 on the Otis Mental Ability Test which was above the established norm for adults. All students had some familiarity with basic automotive tools and test equipment.

Pre-Experimental Data Collection

Prior to actual administration of experimental treatments the first or pre-experimental instructional phase was conducted. Initially, the film strip and record presentation was made to each class. Immediately after this instruction was given, the ignition system knowledge examination was administered. Students were allowed as much time as needed to complete the exam. This was followed by administration of the Otis Mental Ability Test. Standard directions given in the test manual were used.

Collection of Experimental Data

Initially, students from the entire sample were randomly assigned to one of the three treatment groups. In order to compensate for possible differences between students enrolled in separate classes, random assignment was made for each class separately rather than for the entire group. The randomization process is presented in Table 4.

TABLE 4

RANDOMIZATION OF SAMPLE BY CLASS

	Treatment Groups		
	equipment	program	text
Class A	5	5	5
Class B	5	5	6
Class C	5	5	4
Total	15	15	15

All students received their respective treatments in the building where automotive instruction was regularly conducted. A classroom was provided for the program and text groups. The equipment group used a shop area equipped with six automobile engines, three of which were utilized for instruction and three for performance testing.

Program and text treatments were administered concurrently to students selected from a particular class. The equipment treatment was administered sequentially to students selected from the same class.

After each student completed his instructional treatment he was asked to fill out the attitude inventory. Following completion of this instrument, the troubleshooting knowledge examination was administered. After all class members had completed the knowledge examination, performance examinations were conducted individually by one examiner. Upon completion of performance testing, the entire procedure was repeated for students in the other two classes.

IV

FINDINGS

Introduction

The purpose of this chapter is to describe pre-experimental and experimental findings of the investigation. Pre-experimental measures which were analyzed included the Otis Mental Ability Test and student age in months. Experimental measures consisted of a troubleshooting knowledge examination, a troubleshooting performance examination, time required to complete instruction, and an attitude inventory.

Statistical tests employed in the analysis of data were the single factor analysis of variance, single factor analysis of covariance, two factor analysis of covariance, and correlation. A detailed description of these statistics as well as their critical values was described in the previous chapter. The IBM 360/67 computer was used to analyze data obtained from students involved in the study.

Pre-Experimental Data Analysis

Student data was analyzed in order to find out if the three randomly assigned treatment groups were of different ability and age.

Analysis of variance was utilized to determine if the treatment group means differed with respect to ability as measured by the Otis Mental Ability Test. The analysis is summarized in Table 5. No significant differences were found among the groups with respect to the ability variable ($F < 1.00$).

Analysis of data for sources of variation from student age in months is presented in Table 6. The F-ratio ($F < 1.00$) revealed that treatment groups were not significantly different with respect to age.

TABLE 5

ANALYSIS OF DATA FOR SOURCES OF VARIATION FROM OTIS MENTAL ABILITY TEST SCORES

Source of Variation	df	Sums of Squares	Mean Square	F Ratio	Significance
Treatments	2	17.24	8.62	0.08	n.s.
Error	42	4264.40	101.53		
Total	44	104064.36			

TABLE 6

ANALYSIS OF DATA FOR SOURCES OF VARIATION FROM STUDENT AGE IN MONTHS

Source of Variation	df	Sums of Squares	Mean Square	F Ratio	Significance
Treatments	2	181.51	90.76	0.57	n.s.
Error	42	6737.07	160.41		
Total	44	2450933.42			

Analysis of Experimental Data

Comparison Among Groups on the Troubleshooting Knowledge Variable

Single factor analysis of covariance was performed to ascertain if treatment group means differed with respect to the troubleshooting knowledge variable. A summary of this analysis together with listing of control variable means, criterion variable means, and adjusted criterion variable means is presented in Table 7. Adjusted means for the equipment, program, and text treatment groups were 19.95, 21.28, and 21.51. The resultant F-ratio for treatment effects did not exceed the critical value at the .05 level ($F < 1.00$). Thus, the data failed to support rejection of the statistical hypothesis Ho: $\mu_1 = \mu_2 = \mu_3 = \mu_p$ for the troubleshooting knowledge variable.

Comparison Among Groups on the Troubleshooting Performance Variable

The analysis of data for sources of variation from troubleshooting performance examination scores is given in Table 8. Means and adjusted means are followed by an analysis of covariance summary. Results showed an F-ratio for treatment effects statistically significant at the .01 level ($F = 6.24$) indicating rejection of the hypothesis Ho: $\mu_1 = \mu_2 = \mu_3 = \mu_p$ for the performance variable. The equipment group adjusted mean score was 54.14 while program and text group adjusted mean scores were 47.60 and 48.25 respectively. Adjustment to means based upon control variable disparity did not exceed 0.45 for any one mean.

TABLE 7

ANALYSIS OF DATA FOR SOURCES OF VARIATION FROM TROUBLESHOOTING KNOWLEDGE EXAMINATION SCORES

Means and Adjusted Means

Factor	Level	X1 Mean	X2 Mean	Y Mean	Y Adjusted Mean
Grand		16.07	48.09	20.91	
A	1	15.67	47.47	19.73	19.95
A	2	16.33	48.93	21.47	21.28
A	3	16.20	47.87	21.53	21.51

Analysis of Covariance

Source of Variation	df	Sums of Squares	Mean Square	F Ratio	Significance
Treatments	2	20.91	10.46	0.93	n.s.
Error	42	451.85	11.30		
Total	44	472.76			

TABLE 8

ANALYSIS OF DATA FOR SOURCES OF VARIATION FROM TROUBLESHOOTING PERFORMANCE EXAMINATION SCORES

Means and Adjusted Means

Factor	Level	X1 Mean	X2 Mean	Y Mean[a]	Y Adjusted Mean[a]
Grand		16.07	48.09	50.00	
A	1	15.67	47.47	53.69	54.14
A	2	16.33	48.93	47.95	47.60
A	3	16.20	47.81	48.34	48.25
B	1	16.07	48.09	49.98	49.98
B	2	16.07	48.09	50.00	50.00
B	3	16.07	48.09	50.00	50.00
AB	11	15.67	47.47	54.00	54.35
AB	12	15.67	47.47	55.88	56.32
AB	13	15.67	47.47	51.29	51.74
AB	21	16.33	48.93	47.13	46.77
AB	22	16.33	48.93	46.24	45.89
AB	23	16.33	48.93	50.48	50.13
AB	31	16.20	47.87	48.91	48.82
AB	32	16.20	47.87	47.89	47.80
AB	33	16.20	47.87	48.22	48.13

Analysis of Covariance

Source of Variation	df	Sums of Squares	Mean Square	F Ratio	Significance
Treatments	2	1143.82	571.91	6.24	.01
Troubleshooting Performance Dimensions	2	0.01	0.00	0.00	
Treatments X Dimensions	4	316.54	79.13	0.86	n.s.
Error	124	11361.10	91.62		
Total	132	12821.46			

[a] in terms of standard scores

An additional factor in the 3 x 3 design was indicated as dimensions of troubleshooting performance. The three dimensions specified were sub-scores on the performance examination and consisted of information checks made, non-information checks made, and sequence followed. Since test sub-scores were fitted to a mean of 50 with a standard deviation of 10, it was not considered appropriate to test a hypothesis for dimension effects.

There was concern about possible interaction which might exist between treatments and dimensions. It was, therefore, hypothesized that the difference between treatment group means were the same for each of the three dimensions of troubleshooting performance. As analysis of interaction resulted in an F-ratio which was not significant at the .05 level ($F < 1.00$).

Comparison Among Groups on the Treatment Time Variable

Data concerning time in seconds to complete instruction is presented in Table 9. Control variable, criterion variable, and adjusted criterion variable means precede the analysis summary. An F-ratio ($F = 36.94$) for treatment effects was significant at the .01 level. Therefore, the hypothesis Ho: $\mu_1 = \mu_2 = \mu_3 = \mu_p$ was rejected for the treatment time variable. Adjusted mean completion times were 865.13 seconds, 1341.75 seconds, and 774.73 seconds for the equipment, program, and text treatment groups. Adjustments to individual means were -13.07 seconds, +14.30 seconds, and -1.27 seconds respectively.

TABLE 9

ANALYSIS OF DATA FOR SOURCES OF VARIATION
FROM TIME IN SECONDS TO COMPLETE INSTRUCTION

Means and Adjusted Means

Factor	Level	X1 Mean	X2 Mean	Y Mean	Y Adjusted Mean
Grand		16.07	48.09	993.87	
A	1	15.67	47.47	878.20	865.13
A	2	16.33	48.93	1327.40	1341.75
A	3	16.20	47.81	776.00	774.73

Analysis of Covariance

Source of Variation	df	Sums of Squares	Mean Square	F Ratio	Significance
Treatments	2	2765225.20	1382612.60	36.94	.01
Error	40	1497290.52	37432.26		
Total	42	4262515.72			

Comparison Among Groups on the Attitude Variable

Attitude toward instruction which was measured by the attitude inventory is given in Table 10. Adjusted mean scores for the equipment, program, and text treatment groups were 182.81, 186.43, and 182.35. Analysis of covariance resulted in an F-ratio which was not significant at the .05 level ($F < 1.00$). The data, therefore, did not support rejection of the hypothesis Ho: $\mu_1 = \mu_2 = \mu_3 = \mu_p$ for the attitude variable.

Relationships Among Attitude, Knowledge, and Performance Variables for the Three Groups

Correlations among selected criterion variables are presented in Table 11. In order to be assured that correlations of the population from which the sample was drawn were zero, the formula

$$t = \frac{rxy \sqrt{n-2}}{\sqrt{1-rxy^2}}$$

was employed (Hays, 1963). A significant _t_ value with N-2 degrees of freedom would indicate rejection of the second general statistical hypothesis Ho: $rxy = \rho xy$ where ρxy equals zero.

The relationship between troubleshooting knowledge and attitude was positive and significant at the .05 level for the equipment group ($r = .547$). This supported rejection of the hypothesis Ho: $rxz = \rho xz$ where ρxz equals zero. The program and text treatment groups attained negative but non-significant correlations indicating that Ho: $rxz = \rho xz$ was not rejected for these groups.

TABLE 10

ANALYSIS OF DATA FOR SOURCES OF VARIATION FROM ATTITUDE INVENTORY SCORES

Means and Adjusted Means

Factor	Level	X1 Mean	X2 Mean	Y Mean	Y Adjusted Mean
Grand		16.07	48.09	183.87	
A	1	15.67	47.47	182.67	182.81
A	2	16.33	48.93	186.67	186.43
A	3	16.20	47.81	182.27	182.35

Analysis of Covariance

Source of Variation	df	Sums of Squares	Mean Square	F Ratio	Significance
Treatments	2	148.60	70.30	0.27	n.s.
Error	40	10826.25	270.66		
Total	42	10974.86			

TABLE 11

ANALYSIS OF DATA FOR CORRELATIONS AMONG SELECTED CRITERION VARIABLES

r	Treatments		
	Equipment	Program	Text
Attitude and Troubleshooting Knowledge	.547*	-.100	-.347
Attitude and Troubleshooting Performance	.140	-.348	-.680**
Troubleshooting Knowledge and Troubleshooting Performance	.126	.633*	.372

* $P < .05$
** $P < .01$

Troubleshooting performance and attitude correlated negatively for the text group. The relationship was significant at the .01 level ($r = -.680$) and supported rejection of the hypothesis Ho: $r_{yz} = \rho_{yz}$ where ρ_{yz} equals zero. A positive correlation for the equipment group and a negative correlation for the program group were not significant at the .05 level revealing that Ho: $r_{yz} = \rho_{yz}$ was not rejected for these treatment groups.

The correlation between troubleshooting knowledge and troubleshooting performance was positive and significant at the .05 level for the program group ($r = .633$). Thus, data supported rejection of the hypothesis Ho: $r_{xy} = \rho_{xy}$ where ρ_{xy} equals zero. Correlations for the other two groups were also positive but not significant indicating that Ho: $r_{xy} = \rho_{xy}$ was not rejected for the equipment and text treatment groups.

V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

This section provides a summary of the study which was conducted. Information is given about the problem, hypotheses, procedure, and findings.

Introduction

Programed instruction has been indicated as being a sound educational tool. It can be used to teach subject matter in a variety of instructional areas. Research has shown that programed instruction may be used to teach certain aspects of problem solving in a meaningful manner. The question which is posed is whether programed learning methods can be utilized to teach diagnostic problem solving effectively.

Statement of the Problem

The primary objective of this study was to investigate the effects of three methods of teaching diagnostic problem solving (troubleshooting) to automotive students. Experimental comparisons were made among equipment oriented, textbook oriented, and programed self-instructional methods of teaching diagnostic problem solving. In order to make these comparisons, a different method of instruction was presented to each of three student groups.

Hypotheses

1. No differences exist among the three groups in troubleshooting strategy knowledge measured by a multiple choice test as a result of the different instructional methods.

2. No differences exist among the three groups in troubleshooting strategy performance measured by a performance test as a result of the different instructional methods.

3. No differences exist among the three groups in the time taken to complete the three instructional sequences.

4. No differences exist among the three groups in regard to attitude toward instruction received.

5. No relationship exists between students' attitudes toward instruction received and troubleshooting strategy knowledge scores within each of the three groups.

6. No relationship exists between students' attitudes toward instruction received and troubleshooting strategy performance scores within each of the three groups.

7. No relationship exists between students' troubleshooting strategy knowledge scores and troubleshooting strategy performance scores within each of the three groups.

Procedure

The sample utilized in this study consisted of forty-five post-high school male students enrolled in an automotive curriculum at a community college. All students had some familiarity with basic automotive tools and test equipment.

Prior to actual administration of experimental treatments the first or pre-experimental instructional phase was conducted. Initially, the sample received a film strip and record presentation dealing with principles of the ignition system. Immediately after this instruction was given, an ignition system knowledge examination was administered. This was followed by administration of the Otis Mental Ability Test. The two tests were used as control variables in the covariate analysis of data.

Students from the entire sample were then randomly assigned to one of the three instructional treatments: equipment oriented, textbook oriented, and programed instruction. Content of the three treatments was similar in that each presented students with the same three practice troubles to locate. Additionally, a common troubleshooting strategy was taught in each of the respective treatments. In all cases, the instruction presented was individualized in nature and required each student to proceed through the treatment at his own pace.

The equipment oriented instruction was conducted using operational equipment for each student. An instructor assisted the student if he had questions about troubleshooting or problems with the engines.

The programed instruction consisted of a booklet which utilized both linear and intrinsic programing techniques. The booklet allowed students to "find" three different troubles in each of three different hypothetical engines. The troubles were identical to those which were used in the equipment oriented instruction.

The textbook oriented instruction also provided the student with troubles to locate. Content comparable to the programed instruction treatment was used without including any reinforcement principles.

After each student completed his instructional treatment he was asked to fill out an attitude inventory. Following completion of this instrument, a troubleshooting knowledge examination was administered. After all class members had completed the knowledge examination, a performance examination was administered. The performance examination required each student to locate troubles which had been placed in otherwise operational automobile engines. The troubles included in the criterion measure were different from those used in the three instructional treatments.

Findings

Single factor analysis of covariance was performed to determine whether differences existed among any of the treatment means with respect to troubleshooting knowledge, time to complete instruction, and attitude variables.

No differences were found among treatment groups in mean scores on the troubleshooting knowledge examination or in attitude toward instruction received. A significant F-ratio ($p < .01$) favored the equipment treatment group and text group over the program group in shortest amount of time to complete instruction.

A two factor analysis of covariance was employed to investigate possible differences among groups with regard to the troubleshooting performance variable. Results showed an F-ratio which was significant at the .01 level. The equipment group had an adjusted mean score of 54.15 while program and text adjusted mean scores were 47.60 and 48.25 respectively. Since dimensions or test sub-scores were fitted to a mean of 50, it was not considered appropriate to test the hypothesis for dimension effects. Interaction between treatments and dimensions was not significant.

The correlation between troubleshooting knowledge and attitude was positive and significant ($p < .05$) for the equipment treatment group. Correlations between troubleshooting knowledge and attitude for the program and text groups were not significant.

Troubleshooting performance and attitude correlated negatively and significantly ($p < .01$) for the text treatment group. Equipment and program groups did not attain significant correlations with regard to these variables.

The correlation between troubleshooting knowledge and troubleshooting performance was positive and significant ($p < .05$) for the program treatment group. Correlations between these variables were not significant for the equipment and text groups.

Conclusions

Pre-Experimental Data

Ability and age data were obtained from each student involved in the study. Single factor analysis of variance was performed to determine if students assigned to each of the three treatment groups differed with regard to ability and age variables. Analysis revealed no significant differences among treatment groups in ability as measured by the Otis Mental Ability Test and age in months.

The results indicate that students assigned to each of the three treatment groups were comparable with regard to ability and age. The lack of significant differences among groups on these variables provides evidence that randomization had assured treatment group equality.

Experimental Data

This section presents conclusions which were drawn from experimental findings given in the previous chapter. The statement of each null hypothesis is followed by conclusions based upon findings for the particular hypothesis.

Hypothesis 1. The first hypothesis stated that no differences exist among the three groups in troubleshooting strategy knowledge measured by a multiple choice test as a result of the different instructional treatments.

A summary of data relative to the troubleshooting knowledge variable is found in the previous chapter. Results of the analysis of covariance indicated that group means were not significantly different with respect to this variable. Therefore, rejection of the hypothesis dealing with troubleshooting knowledge was not supported.

Results of the present study relative to the knowledge variable are in agreement with research dealing with programed instruction cited by Silberman (1962). His review of numerous research studies indicated that the most consistent finding was no significant difference among treatments.

It appears that, with regard to knowledge aspects of troubleshooting, programed instruction as utilized in the present study is comparable to those methods employing text instruction or actual equipment. The fact that students in the program and text treatment groups scored slightly above but not significantly better than the equipment group supports findings of research results where comparisons were made between equipment and equipment representations (Smith, 1966). Results indicated that it is reasonable to use less expensive instructional aids when the development of skilled performance is not required. It might, therefore, be beneficial to use programed or text instruction of the type specified in this study as substitutes for equipment instruction if knowledge outcomes are desired.

Hypothesis 2. The second hypothesis stated that no differences exist among the three groups in troubleshooting strategy performance measured by a performance test as a result of the different instructional methods.

The results of analysis of covariance relative to the performance variable showed that group means were significantly different at the .01 level. This difference supported rejection of the hypothesis dealing with troubleshooting performance.

Control variables consisted of scores on an ignition system knowledge test and the Otis Mental Ability Test. Adjustment to means, which did not exceed 0.45 for any one mean, was considered negligible. It may, therefore, be concluded that mean differences were due to treatment effects rather than disparity between control variables and the criterion variable.

Differences in the respective treatment means indicated that the equipment group was superior to the other two groups with regard to this variable. The findings agree with those of Cantor and Brown (1956) who found that troubleshooting training on equipment was superior to training on non-simulator aids. The results, however, are in disagreement with studies which pitted equipment usage against simulator usage in teaching troubleshooting (Standee, et al., 1956; French, 1956; Besnard and Briggs, 1956).

Although this study did not specifically investigate the degree to which a training device should resemble actual equipment (Cox, et al., 1965), variation in fidelity between the equipment treatment and the other treatments appeared to exist.

If certain approaches to instruction are placed on a fidelity continuum ranging from equipment through simulators to aids such as programed instruction and textbooks, some explanation might be provided for conflicting research results. It may be that at a certain point along the continuum, a lack of fidelity becomes detrimental to troubleshooting performance development.

The lack of significant interaction between instructional treatments and troubleshooting performance dimensions clearly indicated that differences between treatment means were the same for each of the three dimensions. It is, therefore, contended that troubleshooting performance dimensions specified in the present study were additive in nature and would logically contribute to a composite criterion measure.

Hypothesis 3. The third hypothesis stated that no differences exist among the three groups in the time taken to complete the three instructional treatments.

Analysis of the time variable using analysis of covariance revealed that treatment group means were significantly different ($p < .01$). Therefore, the hypothesis concerned with instructional time was rejected.

Since adjustment to mean times from the Otis Mental Ability Test and ignition system knowledge examination did not exceed fifteen seconds for any one treatment, it was concluded that very little disparity existed between control variables and the time variable. Thus, significant differences were considered to be due to treatment effects.

Results indicated that the text group took the shortest amount of time to complete instruction. The equipment group averaged 90 additional seconds to complete their treatment while the program group averaged 567 seconds more than the text group.

Several studies have indicated that students who receive longer feedback messages require more time to complete instruction (Gilman, 1967; Wodtke and Gilman, 1966). The fact that textbook instruction, which was completed in the shortest time, was purposely developed without programing implies that a difference in time is based upon whether or not the student received written feedback.

It also appears that written feedback via program instruction may take more time to interpret than feedback from actual equipment. This conclusion is based upon the fact that the equipment group took far less time to complete the instruction than the program group.

Hypothesis 4. The fourth hypothesis stated that no differences exist among the three groups in regard to attitude toward instruction received.

Based upon data obtained from the attitude inventory, analysis of covariance results showed that treatment group means were not significantly different. There were slight differences favoring program and text treatments over the equipment treatment, however, these differences were not significant at the .05 level. Consequently, the hypothesis dealing with attitude toward instruction received was not rejected.

Results of the present study suggest that classroom instruction can be developed which students favor as much as shop instruction. The lack of differences among treatments on the attitude variable provides evidence that students who receive the same instructional content by contrasting methods show little variation in their attitudes toward the instruction received.

Research conducted by Carpenter and Greenhill (1963) gives some indication that individuals have wide attitude tolerance limits for variations in learning. Results of this study also suggest that variations in the learning process do not necessarily affect student attitude. It should be noted, however, that any generalizations from the present study must give consideration to the relatively short time which some students took to complete the instructional treatments.

Hypothesis 5. The fifth hypothesis stated that no relationship exists between students' attitudes toward instruction received and troubleshooting strategy knowledge scores within each of the three groups.

The correlation between attitude and troubleshooting knowledge was positive and significantly different from zero for the equipment group. Correlations for program and text groups were not significantly different from zero. Therefore, rejection of hypothesis 5 was supported for the equipment group only.

Results obtained for the equipment group suggest that students who receive troubleshooting instruction via equipment tend to validly perceive the value of their instruction as applied to a knowledge criterion. The lack of significant correlations between attitude and knowledge for program and text groups indicate that these groups did not perceive their instruction in a meaningful manner as related to troubleshooting knowledge.

Studies reported by Smith and Smith (1964) indicate that attitudes toward programed instruction do not relate to teaching effectiveness of the programs. Findings for hypothesis 5 with respect to the program group are in agreement with these results.

Unfortunately, very few investigations have been conducted which examine the complex relationships between attitudes and behavior (Jahoda and Warren, 1966). This is particularly true with regard to student perceptions of instruction and subsequent behavior as a result of instruction. The present study provides some indication that relationships between attitude and behavior may be dependent upon the particular instructional methodology which is utilized.

Hypothesis 6. The sixth hypothesis stated that no relationship exists between students' attitudes toward instruction received and troubleshooting strategy performance scores within each of the three groups.

Troubleshooting performance and attitude correlated negatively and this correlation was significantly different from zero for the text group. Program and equipment group correlations were not significantly different from zero. Rejection of hypothesis 6 was, therefore, supported for the text group.

The high negative correlation obtained by the text group indicated an inverse relationship between the text student's perception of instruction and his performance based upon that instruction. That is, students who scored lower on the attitude inventory tended to score higher on the performance examination. Since the correlations between attitude and performance within the equipment and program groups were not significant, it may be implied that these groups did not perceive their instruction meaningfully as related to troubleshooting performance.

The results suggest that students who studied text material in a superficial manner reacted favorably to the instruction presented. On the other hand, students who studied the text material in a more diligent manner and subsequently scored higher in troubleshooting performance felt that the text method was a poor way to learn. The fact that a student studying by equipment or program methods reacted favorably or unfavorably to his instruction did not indicate that he would perform any better or worse on the troubleshooting performance examination.

Hypothesis 7. The seventh hypothesis stated that no relationship exists between students' troubleshooting strategy knowledge scores and troubleshooting strategy performance scores within each of the three groups.

The program group obtained a correlation between troubleshooting knowledge and troubleshooting performance which was positive and significantly different from zero. Correlations for the equipment and text groups were not significantly different from zero. This supported rejection of hypothesis 7 for the program group but not for the other two groups.

A lack of significant correlations for equipment and text groups indicates that the respective treatments did not provide students with instruction which was equally meaningful on both knowledge and performance dimensions. The significant correlation obtained by the program group implies that the treatment had a relatively constant effect with regard to knowledge and performance variables.

Knowledge and performance have been identified as being unique criterion measures (Glaser and Klaus, 1962). The correlation obtained by the program group indicates that programing contributed to common variance of the two measures. It appears, therefore, that programed troubleshooting instruction as specified in the present study may provide students with relatively equal development of knowledge and performance capabilities. The contribution which this instructional approach can make is important if a constant relationship between knowledge and performance outcomes is desired.

Recommendations for Further Study

The present study has provided answers to certain specific questions about diagnostic problem solving. Its focus was such that the stated problem could be analyzed in a meaningful manner. The following paragraphs describe recommendations for further study based upon results of this investigation. It is hoped that these recommendations will serve to stimulate future research in the area of diagnostic problem solving which can meaningfully relate to the present findings.

This study was conducted using a sample of post-high school automotive students. Analysis of data revealed that the student sample was quite homogeneous with regard to ignition system knowledge and general ability. Group homogeneity was at least partially due to the fact that all students were high school graduates and were pursuing additional education. By contrast, the high school student enrolled in an automotive curriculum may or may not graduate from high school, and will not necessarily enroll in a post-high school education program. The inferred heterogeneity of high school automotive students indicates that caution should be exercised if findings of the present study are generalized to this student group. It is, therefore, recommended that the investigation be replicated using a sample of high school students. In this manner more specific conclusions may be made about relationships between student heterogeneity and treatment effects.

Certain hypotheses were concerned with relationships between attitude toward instruction and behavior as a result of that instruction. Results regarding these hypotheses provided meaningful information about students' perceptions of different instructional treatments. Unfortunately, researchers in the behavioral sciences have tended to avoid the study of attitudes as related to behavior. Consequently, it is difficult to make meaningful inferences from the present study to other research investigations. The foregoing indicates that additional research must be conducted if the complex relationships between attitudes and behavior are to be identified. It is, therefore, recommended that a theoretical model be developed which specifies relationships between attitude and behavior in an instructional context. The model would provide a meaningful focal point for future research conducted in this area.

This study placed primary emphasis on the comparison of three unique instructional methods. Students who were exposed to equipment oriented instruction solved troubleshooting problems with greater proficiency than did students who received other methods of instruction. If troubleshooting instruction is to be taught using actual equipment, meaningful comparisons must be made between the various ways a student can learn when using actual equipment. In this manner, some of the shortcomings associated with equipment oriented troubleshooting instruction may be eliminated. A third recommendation, therefore, specifies that equipment oriented troubleshooting instruction be assessed to determine if modifications to hardware produce changes in troubleshooting performance.

The present study was purposely limited to instruction which taught students to solve relatively simple problems. Other instructional areas such as electronics may require the student to solve more complex problems. Although application of the present findings may be made to other instructional areas, consideration should be given to the degree of problem complexity. In order to provide a more meaningful data base for the present study, it is recommended that additional research be conducted to investigate the possible relationships between media variations and degree of problem complexity.

REFERENCES

Air Training Command. Improvement of Grading Practices for Air Training Schools. ATRC Manual 50-4. Illinois: Scott Air Force Base, 1951.

Anderson, Richard C. "Can First Graders Learn an Advanced Problem Solving Skill?" Journal of Educational Psychology. Vol. 56, No. 6, 1965, pp. 283-294.

Besnard, Guy G. and Briggs, Leslie J. Comparison of Performance Upon the E-4 Fire Control System Simulator and Upon Operational Equipment. AFPTRC-TN-56-47. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, 1956.

Blank, Stanley S. and Covington, Martin. "Inducing Children to Ask Questions in Solving Problems." Journal of Educational Research. Vol. 59, No. 1, 1965, pp. 21-27.

Briggs, Leslie J. and Besnard Guy G. "Experimental Procedures for Increasing Reinforced Practice in Training Air Force Mechanics for an Electrical System." Symposium on Air Force Human Engineering and Training Research. Edited by Glen Finch and Frank Cameron. Baltimore: Air Research and Development Command, 1956, pp. 48-58.

Bryan, Glenn L. "The Training of Electronics Maintenance Technicians." Training Research and Education. Edited by Robert Glaser. Pittsburgh: University of Pittsburgh Press, 1962.

Bryan, Glenn L.; Bond, Nicholas A., Jr.; LaPorte, Harold R., Jr.; and Hoffman, Lyle S. Electronics Troubleshooting: A Behavioral Analysis. Technical Report No. 13. Los Angeles: University of Southern California, 1956.

Bryan, Glenn L. and Schuster, Donald H. An Experimental Comparison of Troubleshooting Training Techniques. Technical Report No. 30. Los Angeles: Department of Psychology, University of California, 1959.

Bureau of Naval Personnel. Constructing and Using Achievement Tests. Washington: U.S. Government Printing Office, 1952.

Campbell, Donald T. and Stanley, Julian C. Experimental and Quasi-Experimental Designs for Research. Chicago: Rand McNally, 1963.

Cantor, J. H., and Brown, J. S. An Evaluation for the Trainer-Tester and Punchboard-Tutor as Electronics Troubleshooting Aids. Port Washington, New York: Special Devices Center, Office of Naval Research, 1956.

Carpenter, C. R., and Greenhill, L. P. Comparative Research on Methods and Media for Presenting Programed Courses in Mathematics and English. University Park: The Pennsylvania State University, 1963.

Cook, Desmond L. "Teaching Machine Terms: A Glossary." Audiovisual Instruction. Volume 6, 1961, p. 152.

Cox, John A.; Wood, Robert O., Jr.; Boren, Lynn M.; and Thorne, H. Walter. Functional and Appearance Fidelity of Training Devices for Fixed-Procedures Tasks. Alexandria, Virginia: The George Washington University Human Resources Research Office, 1965.

Cronbach, Lee J. Essentials of Psychological Testing. New York: Harper, 1960, p. 392.

Crowder, Norman A. "On the Differences Between Linear and Intrinsic Programming." Phi Delta Kappan. March, 1963, pp. 250-254.

Dale, H.C.A. "Fault-Finding in Electronic Equipment." Ergonomics. 1958, pp. 356-385.

DeCecco, John P. Educational Technology. New York: Holt, Rinehart, and Winston, Inc., 1964.

Delco Remy Division. 20,000 Volts Under the Hood. Anderson, Indiana: General Motors Corporation. (Undated.)

Educational Testing Service. Multiple-Choice Questions: A Close Look. Princeton, New Jersey: Educational Testing Service, 1963.

Edwards, Allen L. Experimental Design in Psychological Research. New York: Holt, Rinehart and Winston, Inc., 1964.

English, Horace B. and English, Ava, C. A Comprehensive Dictionary of Psychological and Psychoanalytical Terms. New York: Longrams, Green and Company, 1958.

Fattu, N. A. A Catalog of Troubleshooting Tests. Report No. 1. Bloomington: Institute of Educational Research, Indiana University, 1956.

Fattu, Nicholas A. and Mech, E. Victor. "The Effect of Set on Performance in a Troubleshooting Situation." Journal of Applied Psychology. Vol. 37, No. 3, 1953, pp. 214-217.

Fattu, Nicholas A. and Medley, Donald M. Rationale and Construction of the K-Systems Performance Test. Bloomington: Institute of Educational Research, Indiana University, 1952.

Feurzeig, W.; Munter, P.; Swets, J.; and Breen, M. "Computer Aided Medical Diagnosis." Journal of Medical Education. Vol. 39, 1964, pp. 746-754.

Finch, Curtis R. The Development of an Instrument to Measure Student Attitude Toward Individualized Shop and Laboratory Instruction. Research Series, Number 2. University Park: Department of Vocational Education, The Pennsylvania State University, January, 1969.

Ford Motor Company. Automotive Electrical Circuits, Principles and Problem Diagnosis. Dearborn, Michigan: Ford Motor Company, 1966.

French, Robert S. "Evaluation of a K-System Trouble-Shooting Trainer." Symposium on Air Force Human Engineering, Personnel and Training Research. Edited by Glen Finch and Frank Cameron. Baltimore: Air Research and Development Command, 1956, pp. 160-165.

Gagné, Robert M. The Conditions of Learning. New York: Holt, Rinehart, and Winston, Inc., 1965, p. 282.

Gagné, Robert M. and Brown, Larry T. "Some Factors in the Programing of Conceptual Learning." Journal of Experimental Psychology. Vol. 62, No. 4, 1961, pp. 312-321.

Gagné, Robert M. and Dick, Walter. "Measures in a Self-Instructional Program." Psychological Reports. Vol. 10, 1962, pp. 131-146.

Gagné, Robert M. and Fleishman, Edwin A. Psychology and Human Performance. New York: Henry Holt and Company, 1959.

Glanzer, Murry. "Diagnostic (Troubleshooting) Skills and Their Evaluation." Occupational Psychology. 1958, p. 237.

Glaser, Robert and Klaus, David J. "Proficiency Measurement: Assessing Human Performance." Psychological Principles of System Development. Edited by Robert M. Gagné. New York: Holt, Rinehart, and Winston, Inc., 1962, pp. 419-474.

Glaser, Robert and Phillips, J. C. An Analysis of Proficiency for Guided Missile Personnel: Patterns of Troubleshooting Behavior. Technical Bulletin 55-16. Pittsburgh: American Institute for Research, 1954.

Gilman, David A. "Feedback, Prompting, and Overt Correction Procedures in Nonbranching Computer-Assisted Instruction Programs." Journal of Educational Research. June, 1967, pp. 423-426.

Goldbeck, Robert A.; Bernstein, Benjamin B.; Hillix, W. A.; and Marx, Melvin H. "Application of the Half-Split Technique to Problem Solving Tasks." Journal of Experimental Psychology. Vol. 53, No. 5, May, 1957, pp. 330-338.

Good, Carter V., Ed. Dictionary of Education. New York: McGraw Hill, Inc., 1959.

Harris, Norman C., "Redoubled Efforts and Dimly Seen Goals." Phi Delta Kappan. April, 1965, pp. 360-365.

Hays, William L. Statistics for Psychologists. New York: Holt, Rinehart and Winston, Inc., 1963, p. 529.

Highland, Richard W.; Newman, Slater, E.; and Waller, Harry S. "A Descriptive Study of Electronic Troubleshooting." Symposium on Air Force Human Engineering Personnel and Training Research. Edited by Glen Finch and Frank Cameron. Baltimore: Air Research and Development Command, 1956, pp. 173-198.

Jahoda, Marie and Warren, Neil, eds. Attitudes. Baltimore: Penguin Books, Inc., 1966.

Johns, Kenneth W. "A Comparison of Two Methods of Teaching Eighth Grade General Science: Traditional and Structured Problem Solving." Unpublished Doctoral Dissertation, University of Arizona, 1966.

Johnson, Roger L. The Use of Programmed Learning and Computer-Based Instruction Techniques to Teach Electrical Engineering Network Analysis. Report R-29. Urbana: Coordinated Science Laboratory, University of Illinois, 1966.

Katz, Daniel. "Functional Approach to the Study of Attitudes." Public Opinion Quarterly, Summer, 1960, pp. 163-192.

Likert, Renis. A Technique for the Study of Attitudes. Archives of Psychology, Number 40. New York: Columbia University, 1932.

Lumsdaine, A. A. "Instruments and Media in Instruction." Handbook of Research on Teaching. Edited by N. L. Gage. Chicago: Rand McNally, 1963, p. 584.

Miller, Robert B. and Slebodnick, Edward B. Research for Experimental Investigations of Transferable Skills in Electronic Maintenance. AFPTRC-RT-582. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, 1958.

Moore, J. V., Saltz, E., and Hoehn, A. J. Improving Equipment Maintenance by Means of a Preplanning Technique. AFPTRC-TN-55-26. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, 1955.

Myers, L. B.; Carter, R. G.; and Stover, R. E. The Evaluation of Troubleshooting Strategies. NAVTRADEVCEN 1231-1. Port Washington, New York: U.S. Naval Training Device Center, 1964.

Otis, Arthur S. Manual of Directions for Gamma Test. New York: Harcourt, Brace and World, Inc., 1954.

Popham, W. James. Educational Statistics: Use and Interpretation. New York: Harper and Row, 1967.

Ray, Wilbert S. "Verbal Compared with Manipulative Solution of an Apparatus-Problem." American Journal of Psychology. Vol. 70, 1957, pp. 289-290.

Rosenberg, J. M. Automation, Manpower, and Education. New York: Random House, 1966, p. 6.

Schill, William and Arnold, Joseph P. Curricula Content for Six Technologies. Urbana: University of Illinois, 1965.

Schramm, Wilbur. Programmed Instruction - Today and Tomorrow. New York: Fund for the Advancement of Education, 1962.

Schuster, Donald H. Logical Electronic Troubleshooting. New York: McGraw Hill, 1963.

Seidel, Robert J. and Hunter, Harold G. The Application of Theoretical Factors in Teaching Problem Solving in Programed Instruction. Technical Report 68-4. Alexandria, Virginia: The George Washington University Human Resources Research Office, 1968.

Shettel, Harris H.; Angell, David; and Lumsdaine, Arthur A. Final Report: Self-Instructional Programs for SAGE System Operators. Pittsburgh: American Institute for Research, 1961.

Silberman, H. F. "Characteristics of Some Recent Studies in Instructional Methods." Programed Learning and Computer Based Instruction. Edited by J. E. Coulson. New York: Wiley, 1962, pp. 13-24.

Smith, Karl U. and Smith, Margaret F. Cybernetic Principles of Learning and Educational Design. New York: Holt, Rinehart, and Winston, Inc., 1966, pp. 300-328.

Smith, Robert G., Jr. The Design of Instructional Systems. Technical Report 66-18. Alexandria, Virginia: The George Washington University Human Resources Research Office, 1966.

Standlee, L. S.; Popham, W. J.; and Fattu, N. A. A Review of Troubleshooting Research. Report No. 3. Bloomington: Institute of Educational Research, Indiana University, 1956.

Stolurow, Lawrence M.; Hodgson, Thomas F.; and Silva, John. Transfer and Retroactive Effects of Association Reversal and Familiarization Training in Troubleshooting. AFPTRC-TN-57-46. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, 1957.

Thomas, Francis H.; French, Elizabeth G.; and Travers, Robert M. W. "Variables Related to Problem Solving Effectiveness in Two Types of Problem Situation." Symposium on Air Force Human Engineering and Training Research. Edited by Glen Finch and Frank Cameron. Technical Report 56-8. Baltimore: Air Research and Development Command, 1956, pp. 276-285.

U.S. Department of Labor. Dictionary of Occupational Titles. Volume 1. Washington, D.C.: U.S. Government Printing Office, 1965.

U.S. Department of Labor. Occupational Outlook Handbook. Washington, D.C.: U.S. Government Printing Office, 1968, p. 399.

Warren, Neil D.; Ford, James S.; and Schuster, Donald H. Development of a Trouble Locator and Evaluation of a Generalized Electronic Troubleshooting Course. AFPTRC-TR-58-2. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, 1958.

Wodke, Kenneth H. and Gilman, David A. "Some Comments on the Efficiency of the Typewriter Interface in Computer-Assisted Instruction at the High School and College Level." Experimentation with Computer-Assisted Instruction in Technical Education. Semi-Annual Progress Report. University Park: Computer-Assisted Instruction Laboratory, The Pennsylvania State University, June, 1966.

APPENDIX A

Information Sheet and Troubleshooting Chart
Used for Equipment Instruction

TROUBLESHOOTING THE AUTOMOBILE ENGINE

This material will help you to learn how to troubleshoot the automobile engine under emergency conditions. Information is presented in a convenient, easy-to-use form. It is a step-by-step approach that give you the information you need and helps you to remember. It lets you work at your own pace. When you have completed this instruction you will be tested to see how well you can troubleshoot the automobile engine.

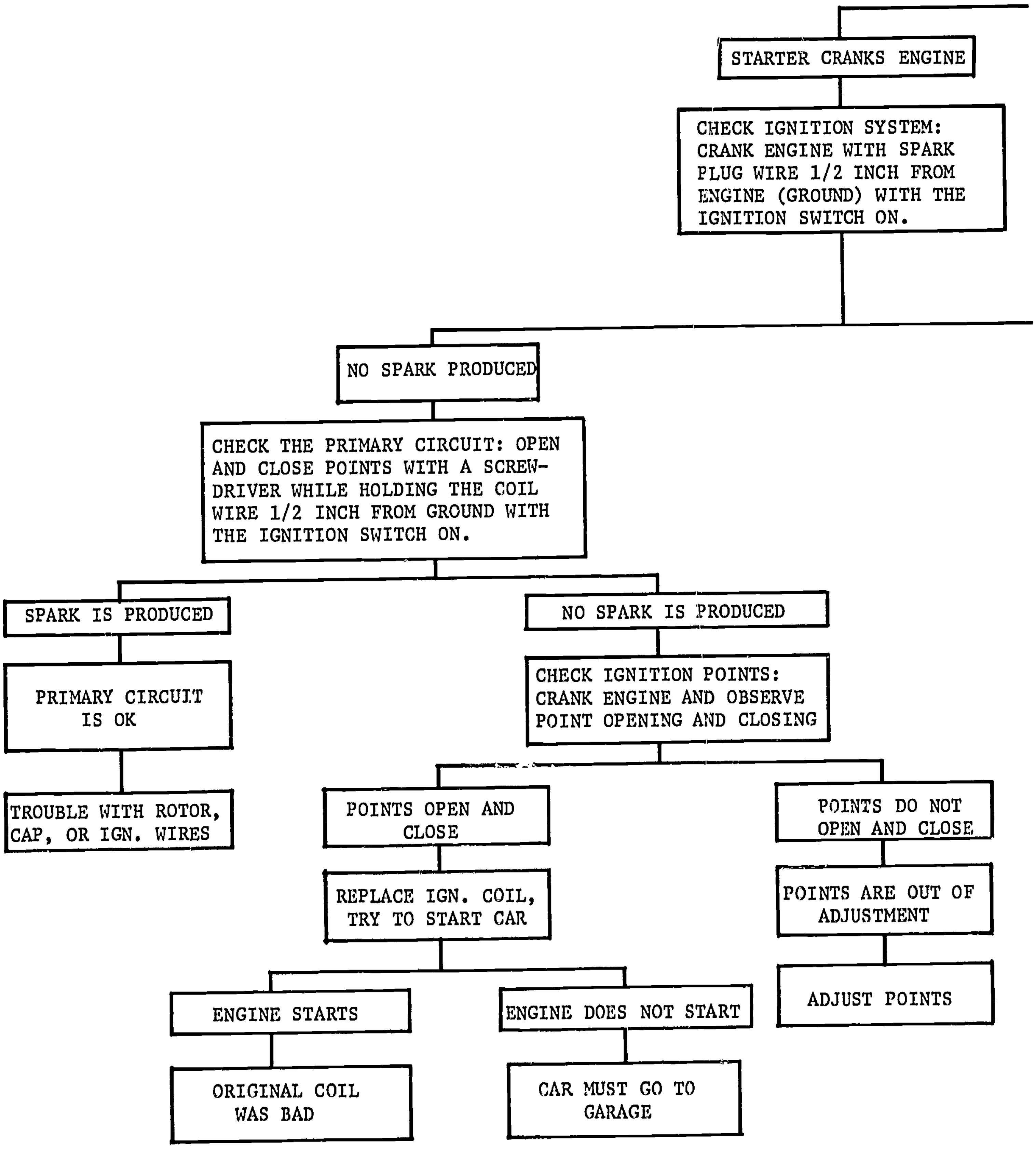
In order to learn how to troubleshoot the automobile engine, you will be finding troubles which have been placed in a "live" engine. You will be assigned to an engine and the instructor will place troubles into the engine, one at a time. For all the troubles you will be finding, the "Customer" has said "the car won't start." This is a symptom and is only an indication that trouble is somewhere in the engine.

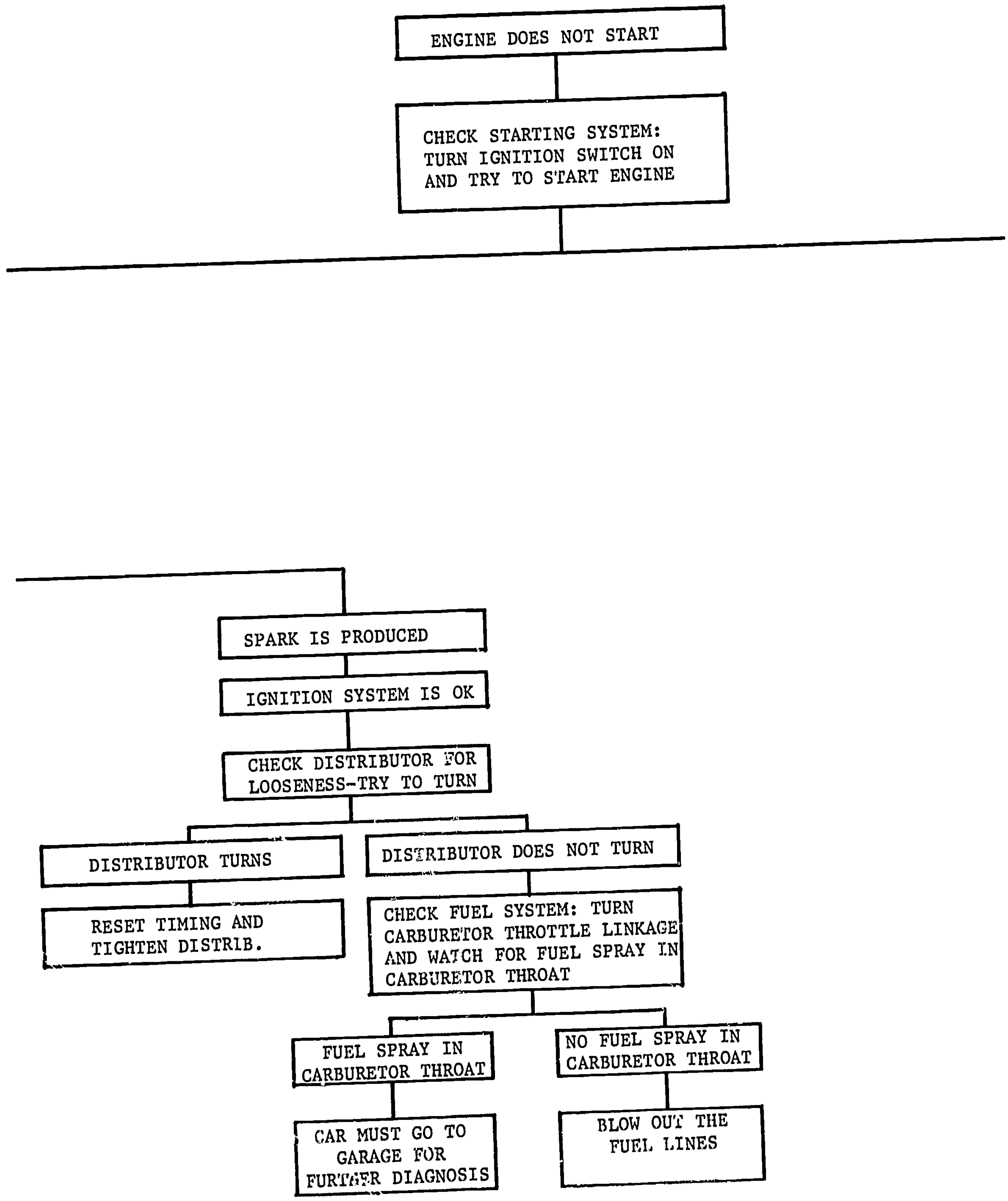
You will be using a "roadmap" to help find each trouble. By using the "roadmap," you can locate the trouble easier and quicker. Start at the top of the page and perform the test <u>in sequence</u>. The results of each test will tell you what is wrong or what to check next.

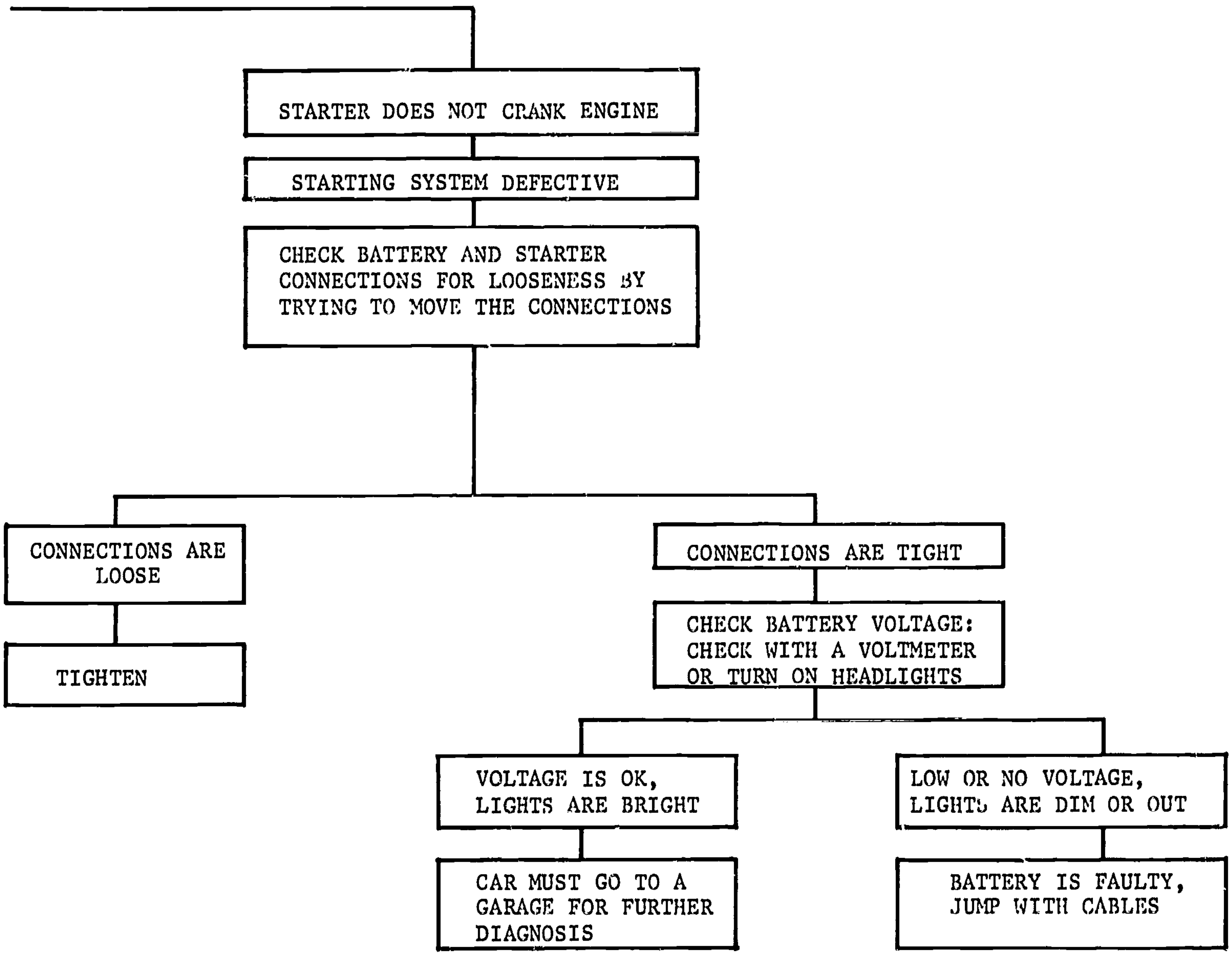
After you have found the first trouble, call the instructor and he will place another trouble into the engine. If you have any problems with the engine or questions about troubleshooting, call the instructor. Also, if you need any replacement parts or special test equipment, tell the instructor. Now check the "roadmap" to be sure that you understand how it works.

When you think that you know how the "roadmap" works, tell the instructor and he will assign you to an engine.

ENGINE TROUBLESHOOTING CHART
(for emergency conditions)




ENGINE DOES NOT START
CHECK STARTING SYSTEM: TURN IGNITION SWITCH ON AND TRY TO START ENGINE
SPARK IS PRODUCED
IGNITION SYSTEM IS OK
CHECK DISTRIBUTOR FOR LOOSENESS-TRY TO TURN
DISTRIBUTOR TURNS
RESET TIMING AND TIGHTEN DISTRIB.
DISTRIBUTOR DOES NOT TURN
CHECK FUEL SYSTEM: TURN CARBURETOR THROTTLE LINKAGE AND WATCH FOR FUEL SPRAY IN CARBURETOR THROAT
FUEL SPRAY IN CARBURETOR THROAT
CAR MUST GO TO GARAGE FOR FURTHER DIAGNOSIS
NO FUEL SPRAY IN CARBURETOR THROAT
BLOW OUT THE FUEL LINES


STARTER DOES NOT CRANK ENGINE
STARTING SYSTEM DEFECTIVE
CHECK BATTERY AND STARTER CONNECTIONS FOR LOOSENESS BY TRYING TO MOVE THE CONNECTIONS
CONNECTIONS ARE LOOSE
TIGHTEN
CONNECTIONS ARE TIGHT
CHECK BATTERY VOLTAGE: CHECK WITH A VOLTMETER OR TURN ON HEADLIGHTS
VOLTAGE IS OK, LIGHTS ARE BRIGHT
CAR MUST GO TO A GARAGE FOR FURTHER DIAGNOSIS
LOW OR NO VOLTAGE, LIGHTS ARE DIM OR OUT
BATTERY IS FAULTY, JUMP WITH CABLES

APPENDIX B

Example of Programed Troubleshooting Instruction

The entire program is available
on loan from the Department of
Vocational Education, The Penn-
sylvania State University

A from page 17

The distributor is tight.

You have made the correct choice. Now remember that we first checked the starting system and it was OK. We then checked the ignition system and it was OK. The last check we made was to see if the distributor was loose and we found it to be tight. Now we will move on to check another system.

Which of the following should we check next?

A. Check the distributor system. (turn to page 21)

B. Check the starting system. (turn to page 18)

C. Check the fuel system. (turn to page 22)

D. Check the ignition system. (turn to page 14)

A from page 20

The starting system is faulty and the ignition system should be checked.

Wrong. If the starter cranks the engine, the starting system is OK. Return to page 20, restudy the information, and select another answer.

C from page 11

Check the points.

You may want to check the points first but this check would not give us enough information about which system the trouble might be in. Remember that you should first check the area of the car that will give you the most information so that the trouble can be isolated to a system. This might include the ignition system, the starting system, and the fuel system. So return to page 11, reread the information, and make another selection.

D from page 15

Check the ignition system

We have already checked the ignition system and have found out that it is OK. Would it help to reread the material on page 15? Then you can make another selection.

APPENDIX C

Example of Text Troubleshooting Instruction

The entire text is available
on loan from the Department
of Vocational Education, The
Pennsylvania State University

The battery is often a "troublemaker." To be sure that the battery is at fault you should check the battery voltage with a voltmeter.

If you don't have a voltmeter handy, a quick way to check the battery is to turn on the headlights. If the lights are dim or out the battery is probably at fault.

In this case the meter reading is low and this means your friend's car has a bad battery. You have located the trouble. Now you can get the car started by "jumping" the battery with battery cables.

If the battery had checked out OK, the car would have to go to the garage for further diagnosis. The reason is that you don't usually have any "fancy" test equipment available when you go out on the road to find a trouble in a car.

APPENDIX D

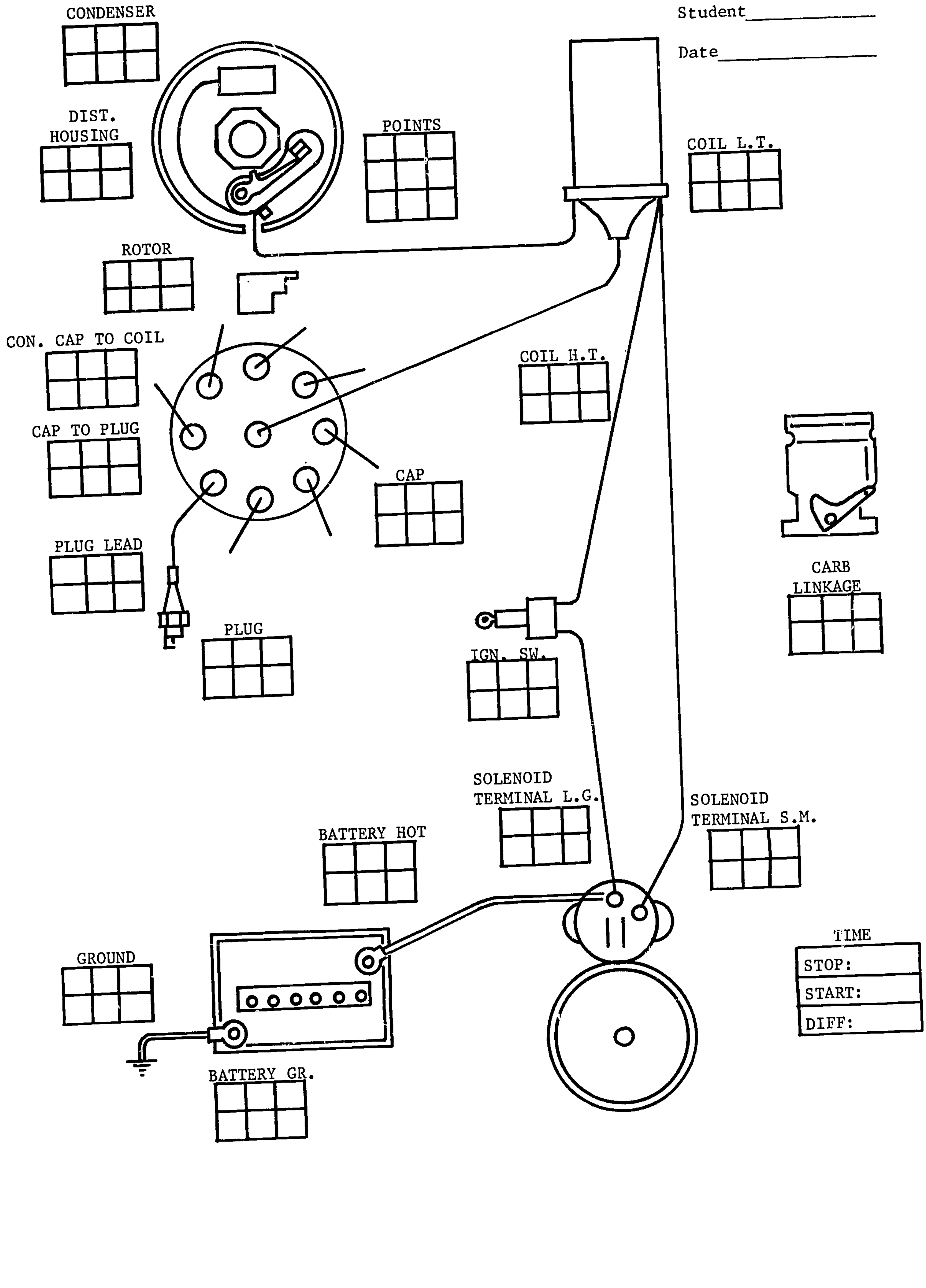
Record of Troubleshooting Behavior and Directions
for Administration of Troubleshooting
Performance Examination

RECORD OF TROUBLESHOOTING
BEHAVIOR

Test No.________

Student________

Date________



OBSERVER'S INSTRUCTIONS FOR THE TROUBLESHOOTING PERFORMANCE EXAMINATION

1. Place the troubles into the three engines. Be sure that the student does not see you do this.

2. Have the student read his INSTRUCTIONS. Give him as much time as he wants to read them.

3. Allow the student to find the first trouble. When he begins, press the stop watch.

4. Number each test or check on the Behavior Record in proper sequence as it is made by the student. Start in the left column of the sheet. If the test or check is made a second time, mark the number in the second column, etc.

   NOTE: If you are not exactly sure what test or check the student is making, ask him what he is doing or what he has just done.

5. Give the student as much time as he wants to find each trouble.

6. If he seems to be done, ask the student if he has completed all the checks which he desires to. If he says "yes," have the student write the trouble in the space provided on his instruction sheet.

7. Press the stop watch and record the elapsed time.

8. Follow the above procedure for the second and third troubles. Use a new RECORD for each trouble.

STUDENTS'S INSTRUCTIONS FOR THE TROUBLESHOOTING PERFORMANCE EXAMINATION

This examination is designed to find out how well you can troubleshoot an automobile engine without the use of special test equipment. You will try to find three troubles, one at a time, which have been placed in three engines. It will be your job to find each trouble using the procedures and checks which were given in the troubleshooting instruction you have just completed. No charts or books may be used to help you. After the exam has started, you may not talk unless the instructor asks you a question. The troubles may not be the same troubles that were used in the instruction which you had. The indication for each trouble is "the car will not start."

In order to get the highest possible score on this examination, you should observe the following suggestions:

1. Use the procedure and sequence that was taught in the instruction which you have just finished.

2. Find each trouble as quickly as possible; you will be timed.

3. Try to make only those checks that will help you to find the trouble.

4. Try to make each check in its proper sequence as was taught to you.

5. Touch only those parts of the engine which you feel will help you to find the trouble.

When you think that you have found each trouble, write the trouble in the space provided below:

The first trouble is ______________________________

The second trouble is ______________________________

The third trouble is ______________________________

Remember that you should try to use the procedures and tests that were just taught to you. When you are sure that you understand these instructions, tell the instructor that you are ready and he will start the examination.

DIRECTIONS FOR SCORING THE TROUBLESHOOTING BEHAVIOR RECORD

1. Information Checks: score one point for each information check which has been made.

2. Non-Information Checks: score one point for each non-information check made; include any information checks made after minimum number of visits. Subtract total number of non-information checks made from 15.

3. Sequence: score one point for each information check which follows in proper sequence after another information check; score one point for first information check if it was made first.

APPENDIX E

Troubleshooting Knowledge Examination

TROUBLESHOOTING KNOWLEDGE EXAMINATION

Directions: The following questions apply to the automotive engine troubleshooting instruction which you have just completed. For each of the questions, select the correct answer from the four possible answers listed. Circle the letter of your choice in each question. Be sure to read each question carefully and take your time.

1. The car does not start but spark is produced as a result of the ignition system check. Which of the following should be checked next?
   a. coil
   b. primary circuit
   c. distributor
   d. ignition points

2. The engine does not start after the original coil is replaced. What does this indicate?
   a. original coil was bad
   b. new coil is faulty
   c. original coil should not have been replaced
   d. car must go to garage for further tests

3. Which of the following checks would be made before the other three when troubleshooting the engine?
   a. check distributor for looseness
   b. check primary circuit
   c. check ignition points
   d. check ignition system

4. Points work properly when the ignition point check is made. What should be done next?
   a. crank the engine
   b. adjust the points
   c. replace the ignition coil
   d. replace the distributor cap

5. What should be done next if the battery voltage is low and the starting system is known to be defective?
   a. check the starter connections
   b. take the car to a garage
   c. check the battery connections
   d. jump the battery with battery cables

6. The distributor turns when the distributor check for looseness is made. What does this mean?
   a. fuel system should be checked
   b. fuel lines should be blown out
   c. car should be taken to a garage for further checks
   d. timing should be reset and distributor retightened

7. What would indicate that the fuel system may not have to be checked?
   a. distributor turns
   b. spark is produced
   c. starter motor turns
   d. battery and starter connections are tight

8. Which of the following indicates that the distributor check for looseness should be the next check made?
   a. starter system is OK
   b. ignition system is OK
   c. battery is OK
   d. primary circuit is OK

9. Which one of the following checks might result in a spark being produced?
   a. battery
   b. distributor
   c. primary circuit
   d. starting system

10. Which of the following should be checked next if a spark is <u>not</u> produced when the ignition system check is made?
    a. fuel system
    b. primary circuit
    c. ignition coil
    d. distributor

11. Which of the following best describes the point check?
    a. adjust as necessary
    b. hold one-half inch from ground
    c. observe opening and closing
    d. replace

12. Which of the following checks require that the ignition switch be turned on?
    a. starting system
    b. primary circuit
    c. ignition system
    d. all of the above

13. What should be checked next if the distributor does not turn and the ignition system is operational?
    a. ignition coil
    b. fuel system
    c. primary circuit
    d. ignition points

14. What would be an indication that the ignition system is working properly?
    a. spark is produced
    b. points open
    c. starter motor turns
    d. primary circuit is OK

15. Which of the following would be checked before the primary circuit is checked?
    a. ignition points
    b. ignition coil
    c. ignition system
    d. ignition distributor

16. A spark is produced at the end of the coil wire when the primary circuit is checked. Which of the following should be checked next?
    a. rotor
    b. ignition points
    c. starter
    d. ignition system

17. There is fuel spray in the carburetor throat when the fuel system check is made. What does this indicate?
    a. the fuel system is OK
    b. fuel lines should be blown out
    c. the car should be taken to a garage for further checks
    d. the ignition system is faulty

18. Which of the following checks should be made first if the engine does <u>not</u> start?
    a. ignition system
    b. fuel system
    c. starting system
    d. distributor system

19. The engine starts after the original coil has been replaced. What does this indicate?
    a original coil was bad
    b. original coil was OK
    c. original coil had a good spark
    d. original coil had the wrong polarity

20. A battery connection is checked and found to be loose. What should be done next?
    a. check the battery connection
    b. tighten the battery connection
    c. jump the battery with battery cables
    d. turn on the headlights

21. A spark is produced as a result of the ignition system check. Which of the following should you check next?
    a. fuel system
    b. ignition system
    c. primary circuit
    d. distributor

22. The starter cranks the engine when the starting system is checked. Which of the following should be checked next?
    a. primary circuit
    b. ignition system
    c. distributor
    d. battery and starter connections

23. Which of the following conditions indicate that the battery voltage should be the next check made?
    a. starter motor turns properly
    b. engine does not start
    c. battery and starter connections are tight
    d. starting system is operational

24. Which of the following conditions would indicate that the points are adjusted properly.
    a. points open
    b. points close
    c. points open and close
    d. all of the above are correct

25. Which one of the following checks should be made first if the starting system is found to be defective?
    a. battery connections
    b. battery voltage
    c. starter motor
    d. starter relay

26. The points do not open and close when the ignition point check is made. What should be done next?
    a. crank the engine
    b. adjust the points
    c. replace the ignition coil
    d. replace the distributor cap

27. Spark is produced at the coil wire when the primary circuit is checked. What does this indicate?
    a. primary circuit is OK
    b. ignition points should be checked
    c. ignition system is faulty
    d. ignition coil should be replaced

28. There is <u>no</u> fuel spray in the carburetor throat when the fuel system check is made. What does this indicate?
    a. the fuel system is OK
    b. fuel lines should be blown out
    c. the car should be taken to a garage for further checks
    d. the ignition system is faulty

29. What should be done next if the battery voltage is OK and the starting system is known to be defective?
    a. replace the battery
    b. jump the battery with battery cables
    c. check the battery connections
    d. take the car to a garage for further checks

30. Which of the following results indicates that the distributor cap should be checked next?
    a. primary circuit is OK
    b. starter is OK
    c. battery is OK
    d. ignition system is OK

APPENDIX F

Attitude Inventory

SHOP AND LABORATORY ATTITUDE INVENTORY

© Curtis R. Finch 1968
Department of Vocational Education
The Pennsylvania State University
University Park, Pennsylvania

DIRECTIONS: Below are several statements about the period of instruction which you have just completed. Read each statement carefully and indicate the degree to which you agree or disagree with it according to the following scale:

SD - Strongly Disagree - I strongly disagree with the statement.

D - Disagree - I disagree with the statement, but not strongly so.

N - Neutral - I am neutral toward the statement or don't know enough about it.

A - Agree - I agree with the statement, but not strongly so.

SA - Strongly Agree - I strongly agree with the statement.

CIRCLE YOUR RESPONSE	..Strongly Disagree	..Disagree	..Neutral	..Agree	..Strongly Agree
1. I would like more instruction presented in this way.	SD	D	N	A	SA
2. I learned more because equipment was available for me to use.	SD	D	N	A	SA
3. This instruction was very boring.	SD	D	N	A	SA
4. The material presented was of much value to me.	SD	D	N	A	SA
5. The instruction was too specific.	SD	D	N	A	SA
6. I was glad just to get through the material .	SD	D	N	A	SA
7. The material presented will help me to solve problems.	SD	D	N	A	SA
8. While taking this instruction I almost felt as if someone was talking with me	SD	D	N	A	SA
9. I can apply very little of the material which I learned to a practical situation. . .	SD	D	N	A	SA

		..Strongly Disagree	..Disagree	..Neutral	..Agree	..Strongly Agree
10.	The material made me feel at ease.	SD	D	N	A	SA
11.	In view of the time allowed for learning, I felt that too much material was presented	SD	D	N	A	SA
12.	I could pass an examination over the material which was presented	SD	D	N	A	SA
13.	I was more involved with using equipment than with understanding the material	SD	D	N	A	SA
14.	I became easily discouraged with this type of instruction	SD	D	N	A	SA
15.	I enjoy this type of instruction because I get to use my hands.	SD	D	N	A	SA
16.	I was not sure how much I learned while taking this instruction.	SD	D	N	A	SA
17.	There are too many distractions with this method of instruction.	SD	D	N	A	SA
18.	The material which I learned will help me when I take more instruction in this area. .	SD	D	N	A	SA
19.	This instructional method did not seem to be any more valuable than regular classroom instruction.	SD	D	N	A	SA
20.	I felt that I wanted to do my best work while taking this instruction.	SD	D	N	A	SA
21.	This method of instruction makes learning too mechanical	SD	D	N	A	SA
22.	The instruction has increased my ability to think	SD	D	N	A	SA
23.	I had difficulty reading the written material that was used	SD	D	N	A	SA
24.	I felt frustrated by the instructional situation.	SD	D	N	A	SA

		...Strongly Disagree	...Disagree	...Neutral	...Agree	...Strongly Agree
25.	This is a poor way for me to learn skills. .	SD	D	N	A	SA
26.	This method of instruction does not seem to be any better than other methods of instruction.	SD	D	N	A	SA
27.	I am interested in trying to find out more about the subject matter	SD	D	N	A	SA
28.	It was hard for me to follow the order of this instruction	SD	D	N	A	SA
29.	While taking this instruction I felt isolated and alone	SD	D	N	A	SA
30.	I felt uncertain as to my performance in the instruction.	SD	D	N	A	SA
31.	There was enough time to learn the material that was presented	SD	D	N	A	SA
32.	I don't like this instruction any better than other kinds I have had.	SD	D	N	A	SA
33.	The material presented was difficult to understand	SD	D	N	A	SA
34.	This was a very good way to learn the material	SD	D	N	A	SA
35.	I felt very uneasy while taking this instruction.	SD	D	N	A	SA
36.	The material presented seemed to fit in well with my previous knowledge of the subject. .	SD	D	N	A	SA
37.	This method of instruction was a poor use of my time	SD	D	N	A	SA
38.	While taking this instruction I felt challenged to do my best work.	SD	D	N	A	SA
39.	I disliked the way that I was instructed . .	SD	D	N	A	SA

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
40. The instruction gave me facts and not just talk	SD	D	N	A	SA
41. I guessed at most of the answers to problems	SD	D	N	A	SA
42. Answers were given to the questions that I had about the material	SD	D	N	A	SA
43. I seemed to learn very slowly with this type of instruction.	SD	D	N	A	SA
44. This type of instruction makes me want to work harder.	SD	D	N	A	SA
45. I did not understand the material that was presented.	SD	D	N	A	SA
46. I felt as if I had my own teacher while taking this instruction.	SD	D	N	A	SA
47. I felt that no one really cared whether I worked or not.	SD	D	N	A	SA

APPENDIX G

Ignition System Knowledge Examination

IGNITION SYSTEM KNOWLEDGE EXAMINATION

Directions: For each of the following questions, select the correct answer from the four possible answers listed. Circle the letter of your choice in each question.

1. What causes a magnetic field to be formed?
   a. circuit resistance
   b. excessive circuit voltage
   c. opposition to current flow
   d. current flow through a wire

2. How many revolutions of the rotor tip are necessary in order that each spark plug will fire in the engine firing order?
   a. one revolution
   b. two revolutions
   c. four revolutions
   d. eight revolutions

3. Where does the ignition circuit release its high-voltage charge?
   a. coil
   b. rotor
   c. condenser
   d. spark plug

4. For the engine to run faster, when must the spark fire?
   a. earlier
   b. later
   c. intermittently
   d. about the same

5. Which of the following is <u>not</u> part of an electrical circuit?
   a. conductor
   b. initiator
   c. load device
   d. power source

6. What surrounds the secondary winding of the coil?
   a. coil core
   b. primary winding
   c. distributor cap
   d. high tension leads

7. What is the primary purpose of the vacuum advance mechanism?
   a. increase power
   b. increase current
   c. increase plug life
   d. increase gas mileage

8. Which of the following is <u>not</u> a part of the ignition system?
   a. coil
   b. battery
   c. generator
   d. distributor

9. What does the spark ignite in the combustion chamber?
   a. gasoline
   b. compression
   c. spark plug
   d. gas-air mixture

10. Between which two strokes does the high voltage spark ignite the mixture in the combustion chamber?
   a. power and exhaust
   b. compression and power
   c. intake and compression
   d. compression and exhaust

11. What supplies the initial power for cranking and ignition?
   a. coil
   b. battery
   c. condenser
   d. generator

12. How many lobes are on the breaker-cam of a four cylinder engine?
   a. two
   b. four
   c. six
   d. eight

13. What is the name of the pressure that moves the current in an electrical circuit?
   a. voltage
   b. amperage
   c. resistance
   d. electricity

14. What material makes up the core of an ignition coil?
   a. iron
   b. steel
   c. copper
   d. aluminum

15. What is the opposition to current flow called?
   a. voltage
   b. amperage
   c. wattage
   d. resistance

16. Which of the following are always contained in a magnetic field?
    a. resistors
    b. conductors
    c. coils of wire
    d. lines of force

17. Which of the following is not a part of the circuit breaking mechanism in the distributor?
    a. rotor
    b. condenser
    c. breaker cam
    d. contact points

18. Which of the following stops current for a fraction of a second?
    a. coil
    b. resistor
    c. condenser
    d. alternator

19. What controls basic timing of the spark to the engine cylinder?
    a. coil
    b. rotor
    c. timing light
    d. distributor shaft

APPENDIX H

Listing of Computer Programs Utilized

The programs listed are available through The Pennsylvania State University Computation Center.

COV	Analysis of Covariance
RELIB	Internal Consistency Reliability
ITEMA	Item Analysis
FAN	Principal Components Factor Analysis
AOVD	Analysis of Variance
COREL	Pearson Product Moment Correlation
VROT	Varimax Rotation