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ABSTRACT

This study was designed to examine the feasibility of using simulation as a means of teaching vocational-technical students to detect and identify malfunctions in selected electrical and mechanical systems. A dynamic simulator was employed which features interchangeable panels and logic that permits the simulation of electrical or mechanical systems in automobiles, heating and air conditioning systems, and various appliances. The study involved 205 automotive mechanics enrollees at four Pennsylvania area vocational-technical schools. The treatment group received individual, self-paced instruction on the simulator and performed significantly better than the non-treatment group which did not receive any simulator instruction. Affective, cognitive, and experience type variables were predictive of troubleshooting efficiency, while cognitive and experience variables predicted success in troubleshooting proficiency. Instructors felt that the simulators motivated students, facilitated instruction, and enhanced learning. (Author/GEB)

THE PENNSYLVANIA STATE UNIVERSITY
DEPARTMENT OF VOCATIONAL EDUCATION

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FINAL REPORT

TROUBLESHOOTING INSTRUCTION IN VOCATIONAL-TECHNICAL EDUCATION VIA DYNAMIC SIMULATION

PDE Projects 10064, 19-1024
Pennsylvania Department of Education
Bureau of Vocational, Technical
and Continuing Education

CURTIS R. FINCH
Principal Investigator

VOCATIONAL — TECHNICAL EDUCATION Research Report

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Curtis R. Finch
The Pennsylvania State University
Principal Investigator

in cooperation with

Berks-West Area Vocational Technical School
Bethlehem Area Vocational Technical School
Centre County Vocational Technical School
Greater Johnstown Vocational Technical School

Pennsylvania Department of Education
Bureau of Vocational, Technical
and Continuing Education

August, 1971

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Curtis R. Finch
Principal Investigator
August, 1971

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SUMMARY

TROUBLESHOOTING INSTRUCTION IN VOCATIONAL-TECHNICAL EDUCATION VIA DYNAMIC SIMULATION

This study was designed to examine the feasibility of using simulation as a means of teaching vocational-technical students to detect and identify malfunctions in selected electrical and mechanical systems. The dynamic simulator which was employed features interchangeable panels and logic that permits the simulation of electrical and/or mechanical systems in automobiles, heating and air conditioning systems, and various appliances. Numerous problems may be easily inserted in each panel and the student may "troubleshoot" each system by pressing buttons at various locations on the panel. The simulator provides immediate feedback for each check which the student performs.

A basic question which this study posed centered around the utility of simulation. That is, (1) Can troubleshooting skills actually be taught via dynamic simulation? Additional questions asked which have relevance to the teaching of troubleshooting skills include: (2) How do teachers perceive the effectiveness of troubleshooting via dynamic simulation? (3) What relationships exist between student characteristics (i.e. ability, motivation) and the learning of troubleshooting via dynamic simulation? (4) What attitudes do students have toward dynamically simulated troubleshooting instruction?

Students involved in the study included 205 automotive mechanics enrollees at four Pennsylvania area vocational-technical schools. After premeasures were administered, students were randomly assigned to treatment and non-treatment groups at each of the four locations. Those in

the treatment group received individual, self-paced instruction on the simulator. The non-treatment group did not receive any simulator instruction.

Students from both groups were evaluated on their ability to find troubles placed in actual equipment. Performance criteria included troubleshooting efficiency, proficiency, redundancy, information checks made, action checks made, and time. Treatment group students were tested as soon as practicable after they had completed simulator instruction. Non-treatment group students were randomly paired with students who had completed the instruction and were tested the same day. Experimental data were analyzed using the multiple linear regression approach. In this manner the effects of certain variables could be partialed out so that simulator effectiveness could be more accurately assessed.

With other independent variables held constant, the treatment group performed significantly better than the non-treatment group on four of the six criterion measures. The simulator appeared to be an effective means of teaching troubleshooting, particularly with regard to problem solving strategy development.

A number of student characteristics variables were significantly related to performance. Affective, cognitive, and experience type variables were predictive of troubleshooting efficiency while cognitive and experience variables predicted success in information checks performance and troubleshooting proficiency. Instructors were generally pleased with the simulator as a teaching device. They particularly felt that it motivated students, facilitated instruction, and enhanced the learning process.

Students reacted to the instructional sequence in a positive manner. Their composite attitude toward simulator instruction was comparable to attitude toward traditional classroom or shop instruction.

I

One of the most difficult tasks which faces an instructor is that of teaching a student how to solve problems. A primary reason for instructional difficulty stems from the fact that problem solving requires an individual to perform at a rather high and complex level. As indicated by Gagné (1965), when a person solves a problem he combines "principles he has already learned into a great variety of novel higher order principles."

In order to teach problem solving in a meaningful manner, provision is often made within a course for the inclusion of practical problem solving experiences. For example, mathematics instructors might provide students with problems to solve which make direct application of the principles taught in class. In science courses, students may use laboratory facilities to solve problems related to classroom instruction. In fact, problem solving experiences can be meaningful to students irregardless of the course one happens to be enrolled in. As indicated by Bruner (1970):

> Good problems, it turns out on closer inspection, are the chief vehicle for good curricula whether one is in an ordinary classroom or alone in a cubicle with a teaching machine.

It is within the area of vocational-technical education that applied problem solving instruction is of utmost importance. A number of occupations require that workers be proficient diagnostic problem solvers or troubleshooters (U.S. Department of Labor, 1965). Students who aspire to these occupations should, therefore, receive experiences which assist them in the development of troubleshooting proficiency.

Ironically, many vocational-technical teachers are not in a favorable position to teach diagnostic problem solving. Although numerous instructional areas rely upon "outside" work to provide students with realistic experiences, customers may hesitate to bring in repair work which involves troubleshooting because they may want a particular automobile or television set repaired in a minimum amount of time. In view of the fact that a school shop or laboratory accepts projects primarily for instructional purposes, it may be several days or even weeks before a particular item is repaired.

An additional instructional problem facing teachers involves the placement of troubles in otherwise operational equipment. The difficulty here lies in the fact that "bugging" tasks usually require an excessive amount of instructor time. Also, the instructor may only be able to put a few of the many possible troubles into equipment, either because he does not have sufficient supply of faulty parts or because the particular equipment does not lend itself to trouble insertion.

A number of investigations has indicated that simulators can provide troubleshooting instruction which is at least equal to that afforded by actual equipment (Standlee, et al. 1956; Trafton, 1962). There are, however, several shortcomings relative to these investigations. First, many of the studies examined special purpose simulators which were oriented toward the solving of specific problems in specific pieces of equipment. The simulators, therefore, were not of a type which allow use in several vocational-technical instructional areas. Second, the subjects utilized in these studies were, for the most part, military rather than civilian students. Consequently, research results may have limited generalizability to vocational-technical high school enrollees, particularly to those students who are culturally and academically disadvantaged.

A final point should be made regarding research in public vocational-technical education which focuses on simulation. Studies dealing with this topic have been, for the most part, concerned with cognitive or verbal skill development (Impellitteri and Finch, 1971). Ultimately, however, vocational objectives are directed toward the application of these skills (and others) in a realistic setting. Not only must the student learn a principle but he should be able to transfer this principle to situations similar to those he will encounter in the work environment. The worth of simulation then lies in the extent to which it can provide acceptable transfer to realistic (work environment type) tasks. Unfortunately, few of the studies conducted in public vocational-technical education have even approached this standard.

Objectives

The primary objective of this project was to examine the feasibility of teaching troubleshooting in vocational-technical education using the dynamic simulation approach. Emphasis was placed on teaching disadvantaged youngsters at the secondary level. More specifically the investigation sought answers to the following questions:

1. What is the general effectiveness of dynamic simulation in teaching troubleshooting?

2. What relationships exist between student characteristics and the learning of troubleshooting via dynamic simulation?

3. What attitudes do students have toward dynamically simulated troubleshooting instruction?

4. How do teachers perceive the effectiveness of trouble-shooting instruction via dynamic simulation?

General Strategy

In order to maximize returns on the research investment, several administrative arrangements had to be made. First it was decided that the study be conducted as a cooperative effort between the Pennsylvania Department of Education, The Pennsylvania State University and several area vocational-technical school districts. In this manner, all cooperating units could provide input to the research staff as the project progressed. Additionally, each unit would be responsible for that aspect of the project which it could handle most efficiently. Subsequently, secondary area vocational-technical schools in four Pennsylvania school districts were identified as having programs that were compatible with the project's outcomes.

A second general concern was with ownership and maintenance of the simulators. It was decided that each school receive a simulator based upon a separate proposal and that receipt of the simulator would be contingent upon agreement to cooperate with the research effort. As part of this agreement, school personnel had the main responsibility of providing students with troubleshooting learning experiences. The research staff identified appropriate learning experiences, specified those students who would receive instruction, and examined outcomes of the experiences. This arrangement enhanced the project's (internal) validity by minimizing the number of confounding variables.

Prior to the time that a simulator was installed in a particular area vocational-technical school, the director and his staff together with the investigator developed a plan for simulator incorporation into the instructional environment. The general plan (which is specified in a later section) allowed for maximum use with minimum instructor involvement and made provision for data to be gathered with a minimum of effort.

II

PROCEDURE

Any research study is, by necessity, limited in scope. As the reader will note in the sections which follow, this particular investigation is no different. Initially, the design of the study is detailed. This is followed by a general description of the simulator which was employed as well as the content to which students were exposed. Following a section devoted to measuring instruments, the sample and specific research activities are described in detail.

Design of the Study

When research is in its planning stages, one is often confronted with the task of controlling certain variables which might confound results. This is particularly true in a situation where several instructors in several schools are teaching students in different grades who have varying personal characteristics. In the above situation, a more traditional research design would only be able to account for few of the dimensions which might be important.

In the present study, which was directed toward a multi-school, multi-teacher, multi-grade sample, it was decided to employ the statistical technique of multiple linear regression. By utilizing this technique, effects of certain independent variables may be partialed out so that the unique contribution which a particular independent variable makes to a dependent variable may be ascertained. Variables included in the analysis may be continuous or catigorical, thus taking into account characteristics such as group membership (i.e., sophomore, junior, senior) and school membership. Further information on the specific program used in this study is contained in Hallberg (1969) while general descriptions of the multiple linear regression technique are described by Bottenberg and Ward (1963) and Smith (1969).

The general model employed was

$$Y = a_o + a_1x_1 + a_2x_2 + \ldots\ldots a_nx_n + e$$

where

Y = dependent variable

$X_1, X_2, \ldots\ldots X_n$ = independent variables

$a_o, a_1, a_2 \ldots\ldots a_n$ = partial regression coefficients

e = error term

The specific equations used in this study were

$$Y_i = a_o + a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4 + \ldots\ldots a_{18}x_{18} + e$$

$i = 1, 6$

where

y_1 = troubleshooting proficiency

y_2 = troubleshooting efficiency

y_3 = troubleshooting redundancy

y_4 = troubleshooting search time

y_5 = troubleshooting action checks

y_6 = troubleshooting information checks

and

x_1 = treatment

x_2 = school

x_3 = grade level

x_4 = verbal ability

x_5 = non-verbal ability

x_6 = motivation toward learning

x_7 = equipment knowledge

x_8 = occupational knowledge

x_9 = age in months

x_{10} = troubleshooting experience in school

x_{11} = troubleshooting experience outside of school

x_{12} = jobs held related to instructional area

x_{13} = hobbies related to instructional area

x_{14} = living area (employment situation)

x_{15} = father's occupation

Several other independent variables were available only for the group that received simulator instruction. These included

x_{16} = attitude toward instruction

x_{17} = time lapse between instruction and performance test

x_{18} = time to complete instruction

The Simulator

In order to dynamically simulate troubleshooting experiences, the System Malfunction Analysis Reinforcement Trainer (SMART) was utilized. This particular unit, which has been developed by Educational Computer Corporation, features interchangeable panels and logic that permits the simulation of electrical and/or mechanical systems in automobiles, heating and air conditioning systems, and various appliances (see Figure 1).

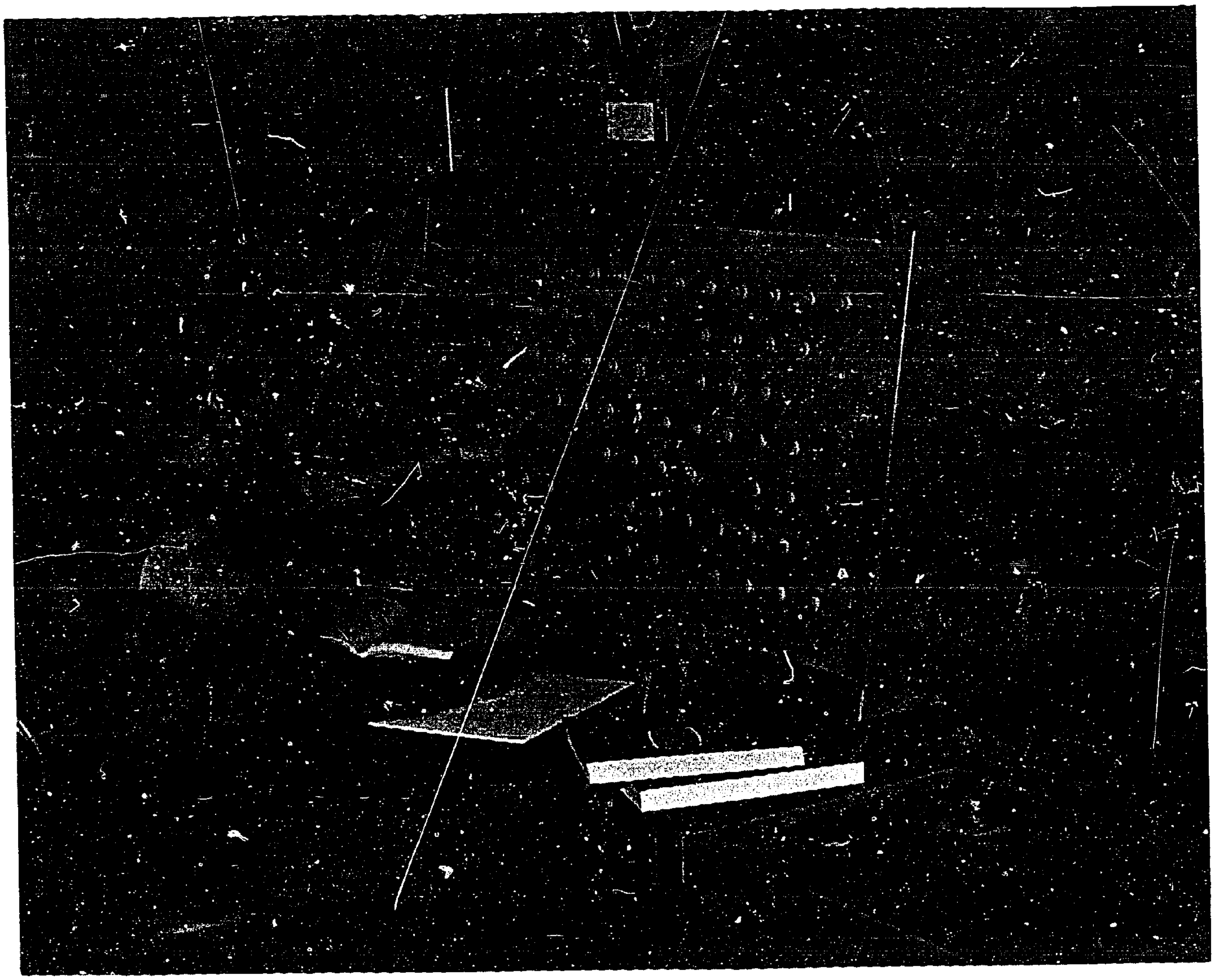
Numerous problems may be easily inserted in each panel and the student "troubleshoots" each system by pressing buttons at various locations on the panel. The simulator provides immediate feedback for each check which the student performs. This feedback can be in the form of pictures or words (on slides) and color indications on the various buttons. Provision for recording student elapsed time to find each trouble as well as checks and repairs/replacements made is also incorporated into the simulator. In addition to its potential as a general purpose simulator, the unit has shown utility in teaching troubleshooting to disadvantaged adults (Educational Computer Corporation, n.d.).

Instruction Content

Although the simulator provided students with feedback as they attempted to "find" troubles, it was also felt necessary to assist them in the development of appropriate troubleshooting strategies. Consequently, each student was provided with a Troubleshooting Booklet which led him through various representative troubles and provided him with a general procedure to follow as he attempted to find each trouble. The material, which was developed by Educational Computer Corporation and modified for use in this study by the research staff, was programed in a linear format. It was written so that instruction could be provided on an individual basis and would be self-paced. Examples of booklet content are presented in Appendix B. By using the booklet each student was able to receive troubleshooting instruction "on his own", however, instructors were able to provide assistance in order that each person would be kept "on the right track."

FIGURE 1

THE SYSTEM MALFUNCTION ANALYSIS REINFORCEMENT TRAINER (SMART)



A troubleshooting Answer Sheet was also developed for use in conjunction with the Troubleshooting Booklet and simulator (see Appendix B). Its purpose was to gather formative data relative to each student's progress on the simulator. At three points in the booklet the student was asked to find a different trouble which was placed in the simulator system. Each trouble was representative of those which he practiced with but was different from any of those in the instructional sequence. For each trouble he was asked to record time to solution, as well as the number of tests and repairs/replacements made. This answer sheet was fashioned after the recording forms used at The Northeast Pennsylvania Technical Center.

Prior to the time that the booklet was used by students, it was reviewed by each of the instructors involved in the experiment. They were asked to review the booklet and react to it in terms of content, sequence, and flow (use in conjunction with the simulator). All instructors felt that the material was satisfactory in this regard. Several errors were noted and corrected. The booklet in final form then consisted of a number of exercises related to troubles in Engine Starting-1 and Engine Starting-2 panels which instructors felt were useful and representative of troubleshooting instruction that a youngster might receive.

Measuring Instruments

In order to gather relevant data from students involved in the study, a number of measuring instruments were used. Several of these, which were standardized measures, are described briefly. Others, that were developed specifically for this study, are explained in greater detail. Copies of measures are presented in Appendix A.

Student Information Sheet

The Student Information Sheet was designed to gather information about student personal background and also to provide some information about each individual's "disadvantagedness." Variables identified with this instrument included school course area, teacher, age, sex, year in school, amount of troubleshooting experience, full-time jobs, hobbies, area where student lived, and several indices of disadvantagedness. Transfer of responses to data cards was provided as an integral part of information sheet development. The completed instrument was administered to twenty-six automotive students enrolled at The Northeast Pennsylvania Technical Center. Based upon reactions of these students, several items were further refined.

Automotive Engine Knowledge Examination

The purpose of the Automotive Engine Knowledge Examination was to obtain some index of student background with regard to the specific equipment. Based upon the primary systems which comprise the automobile engine, a table of specifications was developed. This table indicated the relative weighting of test items of the systems and combination of systems in the automobile engine. Then, items were either selected from existing automobile mechanics examinations or were developed by the principal investigator. The preliminary Automobile Engine Knowledge Examination (AEK) consisted of 51 multiple choice items. An initial administration of the AEK was conducted at the Northeast Pennsylvania

Technical Center. Twenty-six automotive mechanics students who were participating in a MDTA program at the Center comprised the group taking the examination. Data gathered was then processed by computer. The initial analysis resulted in a KR-20 reliability of .82. Results also indicated that five items were discriminating negatively. These items were discarded from the examination prior to the second administration. The second administration with a revised forty-six item test was conducted at the Altoona Vocational-Technical School. Students taking the examination were sophomores, juniors, and seniors enrolled in the Altoona automobile mechanics program. A total of sixty-four students were involved in this administration. Results of the second administration indicated a KR-20 reliability of .73 and KR-21 reliability of .70. All of the items discriminated positively. As an additional validity check, a comparison was made between the mean scores of the sophomore, junior, and senior students. Data for the group was subjected to single classification analysis of variance. Results indicated that the AEK discriminated significantly ($p < .01$) between students with varying amounts of exposure to automotive instruction (senior $\bar{x}$ > junior $\bar{x}$ > sophomore $\bar{x}$).

School Motivation Scale

In order to obtain some measure of student motivation toward school work, it was felt necessary to use an instrument which would provide valid information. The motivation measure chosen was that developed by Russell (1969). It consisted of thirty items which a student reacted to by placing an X in either the "yes" or the "no" column. Results reported by Russell indicate that the scale had adequate reliability on several administrations and correlated with several indices of achievement.

Student Reaction Form

The Student Reaction Form provided students taking simulator instruction with a means of reacting freely to their instructional experience. It consisted of two questions which were both open-ended. The first specified "What did you like best about your instruction on the SMART trainer?" while the second question asked "What did you like least about your instruction on the SMART trainer?"

Troubleshooting Performance Test

This test, which was the dependent variable, evaluated a person's ability to troubleshoot (find troubles in) an automobile engine. For detailed information on the general strategy followed when developing this performance measure, the paper written by Finch and Impellitteri (1970) should be reviewed. A portion of this paper which deals specifically with the performance test used in this study is presented in the next few paragraphs.

The troubleshooting performance measure was designed to meet several unconventional requirements. First, it should evaluate a student's ability to troubleshoot (find troubles in) an automobile engine. Second, it should be appropriate for use with the automotive students of eight instructors in four Pennsylvania vocational-technical schools.

In view of the fact that the project was evaluating troubleshooting simulator effectiveness, the concept of content validity first came to mind. Initial discussions with the eight instructors revealed that the most appropriate index of effectiveness would be transfer to actual equipment. All eight persons agreed on this point. The objective then specified that

> The student will find two troubles placed one at a time in an otherwise operational automobile engine. The basic troubleshooting tools provided by the examiner will include a screwdriver, spark plug wrench, ignition wrenches, pliers, and a test light. There will be no time limit in which to find the troubles.

Since the instructors (who were also tradesmen) agreed that transfer to actual equipment was appropriate, it can be assumed that the educational validity was established to some degree. As an additional check of educational validity, examination was made of the Standards for Automotive Service Instruction in Secondary Schools. This publication, which has been developed by the Automobile Manufacturers--American Vocational Association Industry Planning Council, specifies curriculum standards for automotive programs. It was indicated in the publication as one automotive curriculum objective "to develop an understanding of logical, step-by-step diagnostic procedures" (Standards, 1965, p. 17). Based upon the foregoing information, educational validity was deemed adequate.

Although occupational validity was used as a partial basis for curriculum inclusion, it was felt that additional information should be obtained about the objective. An examination of the Dictionary of Occupational Titles (U.S. Department of Labor, 1965) revealed that a number of jobs in the automobile service area require a worker to have diagnostic capability, particularly with regard to automobile engines. Based upon this information, the objective was felt to be occupationally valid.

There was naturally some concern about face validity (the extent to which the instrument looks like it would measure what it intends to measure). Since the instrument was not administered by instructors, attention was directed toward the examinee. How would he react to the test situation? Observation of 45 students under similar conditions in a previous study (Finch, 1969b) indicated that students reacted positively to the testing environment. It was, therefore, contended that face validity might be adequate for purposes of the present study. A field trial conducted after the present measure was developed also resulted in positive student reactions. It was on the basis of the foregoing that face validity was considered to be satisfactory.

Since the instrument was concerned with physical performance as described by Harmon (1969) (perform an appropriate skilled action in a problem solving situation) and measurement of verbal or attitudinal behaviors were not included, these factors did not need to be taken into account within the development scheme. It was then felt that determination should be made of whether the objective required task procedure and/or task end product measurement. Since the objective specified a rather dichotomous situation (either the trouble is found or it is not found) a decision was made to record the task procedure. In this manner, meaningful information about a student's problem solving strategy could be gathered. A product measurement, on the other hand, would provide very little information with regard to instructional improvement.

The work performance measure required each examinee to locate two troubles which were representative of those an auto mechanic or an advanced automotive student might be required to find. One of the troubles was in the engine fuel system while the other was in the electrical system. Materials used in the examination administration consisted of observer's instructions, student's instruction, and a record of troubleshooting behavior. 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 the troubles. The instrument was designed so that an examiner could accurately record observable behavior without even knowing if this behavior was correct or incorrect. A separate sheet was used to record student behavior for each trouble. Performance sub-scores were established based upon the analysis of data from a previous investigation (Finch, 1969) and a review of research in the area of problem solving performance measurement.

Since the literature review did not identify any specific standards for combining troubleshooting performance sub-scores into a composite performance score, and a number of possible scores could be derived, it was felt best to examine troubleshooting performance as defined by each of the separate sub-scores. These sub-scores or criteria consisted of proficiency, efficiency, redundancy, search time, action checks made, and information checks made. All criteria were developed from data recorded on the behavior record.

Several guidelines were developed for the scoring the troubleshooting performance test. These were necessary in order the criteria could be interpreted in a meaningful manner.

The more proficient troubleshooter was specified as one who tends to find troubles with greater frequency than his less proficient counterpart. Proficiency score was determined on the basis of the number of troubles found. That is, a person finding both troubles would be more proficient than one who found only one trouble or who found no troubles.

An efficient troubleshooter can be defined as one that makes checks which optimize isolation and identification of problems. An optimum number of twelve information checks was established for each of the troubles. This reflected the number of checks needed to identify each of the troubles in an efficient manner. The formula used to determine efficiency score was:

$$E = \frac{InfN}{O} - .02\ (NonInfN)$$

where

E = efficiency

InfN = number of information checks made

NonInfN = number of non-information checks made

O = optimum number of information checks (12)

.02 = constant

A less redundant troubleshooter was specified as one who rechecks the same places to obtain the same information with less frequency than his more redundant counterpart. The formula used to determine redundant counterpart. The formula used to determine redundancy score was:

$$R = 50 - R_{ed}\ N$$

where

R = redundancy score

R_{ed} N = number of redundancies accumulated

50 = constant

Search time was defined as the time in seconds that each person spent attempting to reach solution (find troubles). This time was not "time to find a trouble" but time spent on a trouble since a number of people did not reach solution.

The Action check score consisted of the total number of different points in the system which were visited by an individual. Additionally, the information check score was comprised of the total number of information points visited. An information point may be defined as any action point at which information about the system condition is observable.

Each completed behavior record was analyzed to determine the six performance sub-scores for a particular trouble. Ten of the twelve sub-scores (five fuel problem sub-scores and five ignition problem sub-scores excluding the two proficiency scores) were then converted to standard scores with a mean of 50 and standard deviation of 10. Common sub-scores for each of the two problems were then added together to produce combined sub-scores. This procedure is presented graphically in Table 1. A combined proficiency sub-score was obtained by allowing three points for finding both troubles, two points for finding one trouble and one point for finding no troubles.

Prior to its administration in the research project, an index of interobserver reliability for the test was obtained in a field trial situation. Nine high school auto mechanics students were asked to find a trouble in an otherwise operational automobile engine. The trouble was identical to one of those used in the project. A correlation between

TABLE 1

PROCEDURE USED TO OBTAIN COMBINED PERFORMANCE SUB-SCORES

Sub-scores	Troubles T_1 T_2		Combined Sub-Scores
Efficiency (E)	$E_1 + E_2$	=	E_T
Redundancy (R)	$R_1 + R_2$	=	R_T
Search Time (S)	$S_1 + S_2$	=	S_T
Action Checks (A)	$A_1 + A_2$	=	A_T
Information Checks (I)	$I_1 + I_2$	=	I_T

actual times recorded by observer A and observer B was .997, while the correlation for information checks was 1.0. Since the students' information check scores were converted directly from recorded information, it was felt that the correlations obtained were an accurate index of inter-observer consistency.

Instruction Attitude Inventory

In order that some insight might be gained into student attitude toward simulator instruction, an Instruction Attitude Inventory (IAI) was completed by each student after he had finished his instruction on the simulator. Although not developed specifically for this study, the IAI displays adequate validity and reliability (Finch, 1969a) and has demonstrated its usefulness in a number of research settings.

California Test of Mental Maturity

In order to identify personal characteristics of the students which would relate to academic disadvantagedness, an ability test battery was selected for use in the study. The most appropriate test battery with regard to a mix between amount of pertinent information gathered and administration time was the California Test of Mental Maturity (CTMM). The CTMM, 1963 edition, has what appears to be a good data base with regard to secondary school youngsters (Clark and Tiegs, 1963). Level four of the CTMM was chosen for administration to the students involved in the study.

Short Occupational Knowledge Test

It is virtually impossible to obtain comprehensive information about a person's occupational knowledge in a short period of time. As an alternative to this, it was decided to employ the Short Occupational Knowledge Test (Auto Mechanics) which has been developed by Science Research Associates (Campbell and Johnson, 1970). This test, which consists of twenty multiple choice items, has an adequate reliability index and has been shown to discriminate between auto mechanics and non-auto mechanics with a great deal of precision.

Instructor Reaction Form

In order that some idea of the instructors' feelings about the simulator might be obtained, an Instructor Reaction Form was developed. This instrument consisted of two questions which were both open-ended. The first question specified "list three or four things that you like best about the simulator" while the second asked each instructor to "list three or four things that you like least about the simulator."

...th questions allowed the instructors to provide free (but subjective) reactions about the simulator. The Instructor Reaction Form was used as a basis for development of the Simulator Evaluation Questionnaire described below.

Simulator Evaluation Questionnaire

In order to assess simulator effectiveness from the teacher's vantage point, it was necessary to develop a data gathering device which would be as valid and as objective as possible. It was initially decided to use a questionnaire which incorporated the Likert format (Likert, 1932). Instructors were asked to react to statements about the simulator which they had been using with their classes. Reactions were made by circling the appropriate response on a four point scale ranging from strongly agree to strongly disagree. In this manner objectivity could be maximized. Statements used in the questionnaire came from two sources. First, the investigator developed a listing of statements based upon conversations with teachers and school directors. Additional statements were generated from a free response questionnaire (Instructor Reaction Form) which the instructor group had completed earlier in the school year. The sixty-one statements included in the Simulator Evaluation Questionnaire (see Appendix A) then reflected content validity from an instructor point of view. That is, questionnaire content should represent evaluation areas that instructors feel are important. As statements were being developed, some were noted as being "positive" and some "negative". By including both types of statements in the questionnaire the possibility of response set was minimized.

Sample

Within the research framework it was felt important to identify a sample which would be representative of students receiving troubleshooting instruction in vocational-technical education. This concern was discussed with several vocational school directors at the project's inception and, based upon a general consensus of opinion, it was decided to examine simulator effectiveness using a student group in the auto mechanics area. An in-depth study of automotive troubleshooting instruction via simulation appeared to be feasible since instruction in this area is provided in many vocational-technical schools. Additionally, automotive service involves troubleshooting of electrical and electromechanical systems. In effect, the troubleshooting performed by automotive service personnel is not unlike that performed by persons in other maintenance areas. Systems in the many maintenance areas have generally similar characteristics (electrical and electromechanical). They also require a troubleshooter to apply system knowledge and strategies in order to identify a malfunction.

The sample consisted of all sophomore, junior, and senior automotive students enrolled at Bethlehem, Berks-West, and Centre County Vocational Schools as well as all students in The Service Station Mechanics program at Johnstown AVTS. Half of the remaining automotive students at Johnstown were also included in the sample.

The initial available sample consisted of all those students included above who were available for testing during the fall of 1970. The number of students from whom personal data were gathered totaled 251. A breakdown of students by school and grade level is presented in Table 2.

TABLE 2

DISTRIBUTION OF STUDENTS PROVIDING PERSONAL DATA BY SCHOOL AND GRADE LEVEL

Grade	School				Total
	A	B	C	D	
10	29	14	41	27	111
11	18	14	24	31	87
12	19	7	16	11	53
Total	66	35	81	69	251

The net available sample was composed of those students who, in addition to providing personal data, completed the Automobile Engine Knowledge Examination and the Troubleshooting Performance Test. Of this group (n = 205), 105 made up the treatment group while the control group numbered one hundred. A distribution of students by school, grade, and group is given in Table 3. The lower number of students reported in Table 3 can be attributed to several factors. First, some students were "lost" because they quit or were dismissed from school. Others were not available for performance testing when it was scheduled to be administered. A few youngsters were eliminated because of improper instructional procedures conducted at one school when the project first began. Last, because of time considerations, instruction

TABLE 3

DISTRIBUTION OF NET AVAILABLE SAMPLE BY GROUP, SCHOOL, AND GRADE LEVEL

Grade	School								Total
	A		B		C		D		
	TR	NT	TR	NT	TR	NT	TR	NT	
10	11	8	7	6	21	17	14	12	96
11	9	7	5	5	8	9	13	14	70
12	7	8	4	3	0	6	6	5	39
Total	27	23	16	14	29	32	33	31	205

TR = Treatment (received simulator instruction)

NT = Non-Treatment (did not receive simulator instruction)

and testing was terminated in several schools after a sufficient number of students had completed these activities.

In order to present a more comprehensive profile of the students which were included in the sample, data for several of the variables were compiled. These variables consisted of Language and Non-Language scores on the California Test of Mental Maturity (CTMM) as well as scores from the Short Occupational Knowledge Test (SOKT). The data are presented in Tables 4 through 6. Mean scores for the CTMM and SOKT reflect a general increase across grades with lower mean scores being produced by students at the lower grade levels.

TABLE 4

CTMM LANGUAGE MEAN SCORES BY SCHOOL AND GRADE LEVEL

Grade	School			
	A	B	C	D
10	24.89	27.00	26.37	27.81
11	27.38	34.40	30.53	30.26
12	30.00	30.14	32.17	32.27

TABLE 5

CTMM NON-LANGUAGE MEAN SCORES BY SCHOOL AND GRADE LEVEL

Grade	School			
	A	B	C	D
10	30.95	34.38	36.79	32.27
11	34.25	37.50	35.06	35.26
12	37.47	39.14	37.17	38.73

TABLE 6

SHORT OCCUPATIONAL KNOWLEDGE TEST (AUTO MECHANICS)
MEAN SCORES BY SCHOOL AND GRADE LEVEL

Grade	School			
	A	B	C	D
10	5.00	6.46	6.13	6.46
11	9.62	8.10	8.65	9.22
12	12.80	11.29	10.83	10.18

CTMM language mean scores for 10th, 11th, and 12th graders were found to be consistantly below the norm. Mean scores for 10th graders ranged from the 24th to 34th percentile while mean scores for 11th and 12th grade students ranged from the 27th to 50th percentile and 27th to 34th percentile respectively. Non-language mean scores were substantially higher. Tenth grade students' scores ranged from the 38th to 66th percentile. Eleventh and 12th grade scores ranged from the 46th to 62nd percentile and 58th to 69th percentile respectively.

Since scores for the SOKT are not intended to be presented in distribution form, some comparisons can be made with the category cut-offs provided in the test manual. Tenth and 11th grade mean scores fell into the fail category based upon a national sample of auto mechanics (score of ten or less). However, one of the 12th grade means fell in the pass category (12+) while another fell in the unclassifiable category (11). The two other 12th grade group means approached placement in the unclassifiable category.

Additional descriptive data were available for the student sample. This data was drawn from the Student Information Sheet and consisted of categorial variables.

Twenty-one percent of those students involved in the study indicated that they lived in a farm area while town and city dwellers numbered 54 and 25 percent respectively. Sixty percent of the students specified that some persons in the area where they lived did not have jobs. "Many don't have jobs" was checked by four percent of the group while 34 percent indicated "everyone has jobs." No data was available for two percent.

With regard to students' views of discrimination, eight percent felt that they had been discriminated against at some time while sixty-six percent did not feel this way. Twenty-six percent of the group did not know whether or not they had ever been discriminated against.

Data on father's occupation was compiled as follows: Unskilled = 4%, Semi-Skilled = 33%, Skilled = 41%, Sales = 3%, Technical = 8%, and Professional = 3%, No information = 8%. For the most part, the father's occupation reflected employment in a skilled or semi-skilled area. Nine percent of the student group indicated that their families had been on welfare while 85 percent reacted in a negative manner to this question. Welfare data was not available for six percent of the group.

Research Activities

The following paragraphs have been included in order that one might become familiarized with specific research procedures. They detail critical research activities in a somewhat chronological manner.

Early in the school year, information was gathered about the students constituting the selected sample. Each student's personal background, ability, and motivation were assessed. Instruments used for this purpose included the California Test of Mental Maturity (short form), the Short Occupational Knowledge Test in Automotive Mechanics, a School Motivation Scale, and a Student Information Sheet. Concurrent with the gathering of this information, automotive instructors received an orientation to the simulator and became thoroughly familiarized with its capabilities. This orientation was conducted by the Educational Computer Corporation staff. Additionally, simulators were installed in each of the four cooperating schools and were checked out to assure that they operated properly.

After these activities had been accomplished, instructional materials were then delivered to the eight cooperating teachers. These materials included an Automobile Engine Troubleshooting Booklet and a booklet answer sheet. Instructors were then given sufficient time to review the booklet in conjunction with the simulator. It was asked that instructors study the booklet the same way that their students would. In this manner each instructor would be familiar with the instructional unit and would be able to assist students with any problems encountered on the booklet or the simulator.

After the instructors had become familiar with the troubleshooting booklet and the panels which were to be used with the booklet, other materials were provided to them. These materials included additional copies of the Automobile Engine Troubleshooting Booklet as well as copies of the Instruction Attitude Inventory, Student Reaction Form, and Troubleshooting Answer Sheet. All materials were provided in sufficient numbers so that instructors could use them with designated students. Concurrent with this, students were randomly selected by school, class, and year in school to either the treatment or control group. Additionally, treatment group assignment to instruction was randomly made. Instructors were then asked to present all of their automotive students, both treatment and control, with an introduction to the simulator. They gave a one class period discussion which covered the general operation of the simulator, drawing from the information in the simulator Operator's Manual. This was a general overview and was not intended to include specific troubleshooting instruction. The instructors showed how the simulator operated, where the basic switches were, and what they did. At the same time, instructors told the students that they might get a chance to use the unit sometime during the school year.

In the middle of October, students in the treatment group started receiving simulator instruction. Students received instruction one-by-one according to the pre-arranged schedule. Each instructor in each school gave the designated student a troubleshooting booklet to use and told him not to write in the booklet. He was also asked to contact the instructor if he had any problems using the booklet or the simulator. After each student had completed his instruction on the Engine Starting-1 panel, he asked the instructor to change the panel. At this time the Engine Starting-2 panel, slides and logic were placed on the simulator. After the student had completed all instruction, his booklet and answer sheet were collected and he was provided with an Instruction Attitude

Inventory and a Student Reaction Form to complete. At this time, another student from the treatment group was placed on the simulator.

Approximately three or four weeks after the first student began instruction on the simulator, the principal investigator traveled to each school to test students in terms of troubleshooting performance on actual equipment. Students tested included those who had completed instruction on the simulator as well as those randomly assigned to the control group who were listed "opposite" completed treatment students. The purpose of this evaluation was to measure transfer from simulator to actual equipment. In order to accomplish this task, an engine mounted on a trailer was utilized. This unit was constructed by students at the Centre County Vocational-Technical School under the direction of several instructors. Concurrent with performance evaluation, students completed the Automobile Engine Knowledge Examination. This examination was designed to obtain an up-to-date indication of each student's knowledge with regard to the instructional area. At regular intervals, the test engine was towed to each of the four schools and student troubleshooting ability was assessed.

Periodically, after a sufficient number of measures had been scored, information was placed on data cards. At the conclusion of the experiment, final information was key punched and data were processed using the 360/67 computer. The multiple linear regression approach was utilized to analyze experimental data.

During the later part of the school year, instructor reaction information was gathered and students' attitudes toward classroom and shop instruction were assessed. These data were later compiled and examined in a descriptive manner.

III

FINDINGS

There were several questions posed by this research which focused on the effectiveness of teaching troubleshooting via dynamic simulation. These questions included: What is the general effectiveness of dynamic simulation? What relationships exist between student characteristics and the learning of troubleshooting via dynamic simulation? What attitudes do students have toward dynamically simulated troubleshooting instruction, and how do teachers perceive the effectiveness of troubleshooting via dynamic simulation? Findings relevant to these questions are presented in the following paragraphs. Several of the findings have been developed from rather complex analyses while others are presented in a descriptive manner.

The General Effectiveness of Dynamic Simulation in Teaching Troubleshooting

In order to assess the effectiveness of dynamic simulation it was necessary to determine what unique relationship the prime independent variable, group membership (treatment vs. non-treatment), might have with the six dependent variables (proficiency, efficiency, redundancy, search time, action checks, and information checks). It should first be noted that this independent variable was categorical with the group receiving simulator instruction coded 1 and the control or non-treatment group coded 0. Additionally, proficiency was coded 1, 2, or 3 depending on whether an individual found no troubles, one trouble, or both troubles. The other five dependent variables were continuous and, prior to the analysis, had been derived from raw sub-scores which were first converted to standard scores and then combined.

Independent variable means and standard deviations for the treatment group, non-treatment group, and total sample are provided in Table 7. These include scores on tests and scales which were described in a previous section as well as biographical and school membership data. Variables three through six were coded one for "yes" and two for "no". Employment in home area (variable 7) was coded as follows: everyone has jobs = 1, some don't have jobs = 2, many don't have jobs = 3. Variable eight (father's occupation) consisted of five categories: unskilled = 1, semi-skilled = 2, skilled = 3, technical = 4, professional = 5. School membership variables (18, 19, 20, 21) were coded one for "yes" and zero for "no".

Initially, a zero-order correlation matrix was generated for the six performance (dependent variables and all independent variables. This data is presented in Table 8. Intercorrelations ranged from .389 to -.241. A number of these relationships were significant at or beyond the .05 level. A comment should be made regarding three of the variables. Instruction Attitude Inventory, time lapse, and time to complete instruction scores were only available for those persons completing simulator instruction. Consequently, the correlations have not been included in this particular matrix. They are, however, reported as part of the student characteristics analysis which is presented in a later section.

Multiple linear regression analysis (MRA) was then conducted to identify the unique contribution which each of the independent variables made to the dependent variables. As indicated previously, prime concern

TABLE 7

MEANS AND STANDARD DEVIATIONS FOR THE 21 INDEPENDENT VARIABLES BY TREATMENT GROUP, NON-TREATMENT GROUP, AND TOTAL SAMPLE

Variables	Treatment (n = 105)		Non-Treatment (n = 100)		Total (n = 205)	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
1. Age in months	195.02	12.21	196.39	11.37	195.59	11.78
2. Grade (10,11,12)	10.65	0.73	10.82	0.77	10.73	0.76
3. School Troubleshooting Experience	1.80	0.40	1.79	0.41	1.80	0.40
4. Outside of School Troubleshooting Experience	1.73	0.45	1.55	0.50	1.63	0.48
5. Jobs in Automotive Area	1.65	0.48	1.71	0.88	1.68	0.70
6. Hobbies in Automotive Area	1.38	0.49	1.36	0.48	1.37	0.48
7. Employment in Home Area	1.61	0.53	1.80	0.57	1.71	0.56
8. Father's Occupation	2.77	0.79	2.77	0.87	2.77	0.82
9. Instruction Attitude Inventory	174.84	20.76	a	a	a	a
10. Time Lapse - Instruction and Test (in days)	22.41	17.85	a	a	a	a
11. Time to Complete Instruction (in minutes)	326.03	110.75	a	a	a	a
12. School Motivation Scale	18.21	3.91	18.25	3.83	18.22	3.83
13. Occupation Knowledge Test	7.67	3.96	8.70	4.01	8.09	3.99
14. CTMM Language	29.01	8.34	28.64	8.26	28.74	8.30
15. CTMM Non-Language	35.71	7.02	34.99	7.27	35.30	7.06
16. Engine Knowledge Test	23.04	6.10	22.87	6.00	23.00	6.12
17. Group	1.00	0.00	0.00	0.00	0.51	0.50
18. School A Membership	0.27	0.45	0.23	0.42	0.24	0.43
19. School B Membership	0.29	0.46	0.31	0.46	0.31	0.46
20. School C Membership	0.29	0.46	0.32	0.47	0.30	0.46
21. School D Membership	0.14	0.35	0.14	0.35	0.15	0.35

[a]Data for variables 10, 11, and 12 were not available for the non-treatment group.

TABLE 8

ZERO ORDER CORRELATIONS BETWEEN THE SIX PERFORMANCE VARIABLES AND THE INDEPENDENT VARIABLES FOR TOTAL SAMPLE
(n = 205)

Variables	Profi-ciency	Search Time	Action Checks	Infor-mation Checks	Redun-dancy	Effi-ciency
1. Age	.134	.059	.118	.079	.077	.041
2. Grade	.209**	-.056	.079	.195**	.052	.197**
3. School Troubleshooting Experience	-.184**	.125	-.081	-.148**	-.037	-.138*
4. Outside School Troubleshooting Experience	-.239**	.153*	.020	-.163*	-.111	-.197**
5. Jobs in Automotive Area	-.159*	.183**	.002	-.214**	-.133	-.241**
6. Hobbies in Automotive Area	-.095	.110	.018	-.031	-.023	-.049
7. Employment in Home Area	-.030	.065	-.008	-.034	-.091	-.044
8. Father's Occupation	.025	.012	.054	.019	-.072	-.003
9. Instruction Attitude Inventory	a	a	a	a	a	a
10. Time Lapse-Instruction and Test	a	a	a	a	a	a
11. Time to Complete Instruction	a	a	a	a	a	a
12. School Motivation Scale	.089	-.091	.011	.030	-.059	.020
13. Occupation Knowledge Test	.334**	-.225**	-.057	.135	.164*	.182**
14. CTMM Language	.081	-.152*	-.007	.182**	.105	.216**
15. CTMM Non-Language	.165*	-.079	-.023	.193**	.163*	.236**
16. Engine Knowledge Test	.389**	-.207**	.047	.300**	.164*	.322**
17. Group	-.136	-.068	.175*	.307**	.121	.280**
18. School A Membership	.173**	.078	.112	.000	-.039	-.050
19. School B Membership	-.049	-.035	-.017	.074	.036	.090
20. School C Membership	-.106	-.016	-.049	-.132	-.099	.132
21. School D Membership	-.008	-.028	-.050	.075	.130	.113

[a]Data for variables 10, 11, and 12 were not available for the non-treatment group. Therefore, correlations have been omitted.

* = P < .05

** = P < .01

was with the treatment variable as this differentiated between students receiving and not receiving simulator instruction. Other independent variables were also important to the extent that they made unique contributions to each of the performance variables. Initially, a full model analysis was undertaken to examine the unique information available from each of the 18 independent variables (variables 9, 10, and 11 were omitted from the analysis). This was conducted for each of the six dependent variables. Full model (and subsequent restricted model) analyses were found to have F-ratios significant beyond the .05 level. A number of the variables in the full model did not appear to possess enough unique information to be statistically significant. Therefore, in order to account for all variables and also identify those having the most unique and predictively useful information, a restricted MRA model was calculated. This was conducted using a step-down process. On the basis of the least reduction in sums of squares regression, one independent variable at a time was successively omitted until only those variables with significant partial regression coefficients remained. The level of significance established was .05.

Regression analysis between the independent variables and proficiency for the restricted model is provided in Table 9. Using all eighteen independent variables in the full model yielded a multiple correlation of .5119. The coefficient of determination in the full model adjusted for degrees of freedom was equal .1949. The adjusted coefficient of determination is arrived at by squaring the multiple correlation and then adjusting that figure for the expected shrinkage upon cross validation. When the restricted model was calculated and only variables

TABLE 9

REGRESSION ANALYSIS BETWEEN FOUR INDEPENDENT VARIABLES AND THE DEPENDENT VARIABLE PROFICIENCY

(n = 205)

Variables	Partial Regression Coefficient	Standard Error	Student "t"
5. Jobs in Automotive Area	-.1872	.0874	2.14*
13. Occupation Knowledge Test	.0267	.0112	2.39*
16. Engine Knowledge Test	.2234	.0071	4.08**
18. School A Membership	.9121	.0936	2.39*
Intercept	.9121	.2410	

Standard Error of Estimate = .5665

Multiple Correlation (full model) = .5119

Adjusted Coefficient of Determination (full model) = .1949

Multiple Correlation (four independent variables) = .4741

Adjusted Coefficient of Determination (four independent variables) = .2093

* = P <.05

** = P <.01

with significant partial regression coefficients remained, the multiple correlation was .4741 and the adjusted coefficient of determination was equal to .2093. This adjusted figure indicated a slight gain in precision due to the elimination of less useful variables. In order to interpret relationships between the four significant variables and the criterion, each partial regression coefficient was examined. In general, one unit increase in any of the independent variables results in a change in the dependent variable equal to the size of the partial regression coefficient with the other independent variables held constant. Therefore, a one unit increase in engine knowledge test score corresponds with a .2234 increase in proficiency score. A one unit decrease in jobs in automotive area (coded 1 = yes, 2 = no) is associated with a .1872 increase in proficiency score. Additionally, membership in school A reflected an average proficiency score which was significantly higher than membership in other schools.

Table 10 presents the regression analysis between independent variables and the dependent variable search time. The adjusted coefficient of determination for the full model was .0701 while elimination of fifteen variables yielded an adjusted coefficient of .0817. Variables remaining in the model included age, jobs in automotive area, and occupation knowledge and, while this relationship was low it was significant. When interpreting this table it should be remembered that search time was recorded in seconds. Thus, a higher occupation knowledge test score is associated with a lower search time. Again, variable 17 (Group) did not possess a significant partial regression coefficient and was eliminated in the step-down process.

TABLE 10

REGRESSION ANALYSIS BETWEEN THREE INDEPENDENT VARIABLES AND THE DEPENDENT VARIABLE SEARCH TIME

(n = 205)

Variables	Partial Regression Coefficient	Standard Error	Student "t"
1. Age	.2147	0.973	2.21*
5. Jobs in Automotive Area	3.7681	1.567	2.41*
13. Occupation Knowledge Test	-1.010	0.288	3.51**
Intercept	59.959	18.894	

Standard Error of Estimate = 15.4831

Multiple Correlation (full model) = .3842

Adjusted Coefficient of Determination (full model) = .0701

Multiple Correlation (three independent variables) = .3086

Adjusted Coefficient of Determination (three independent variables) = .0817

* = P < .05

** = P < .01

Regression analysis data for the dependent variable action checks is provided in Table 11. The overall adjusted coefficient of determination (all independent variables included) was .0011 while the restricted coefficient (one variable) increased to .0259. The resultant correlation between the remaining independent variable (Group) and the action checks criterion was moderate (.1751). The t value was significant beyond the .05 level. Thus, on the average, treatment group students scored 5.60 units higher on the action checks variable than did non-treatment students and this was true with the effects of all other independent variables held constant.

Table 12 presents the regression analysis between four independent variables and the dependent variable information checks. The overall adjusted coefficient of determination was .1948 while the restricted coefficient increased slightly to .2103. Thus, elimination of less useful variables through the stepdown process increased predictive efficiency. The multiple correlation was .4751 with four variables remaining in the restricted model. Variable 17 (Group) attained the highest partial regression coefficient and the highest t value (5.02). On the average, students in the treatment group scored 10.65 units higher on the information checks variable than did the non-treatment group. Other variables included in the partial regression model were grade, jobs in automotive area, and engine knowledge. The grade variable and engine knowledge variable were positively related to number of information checks made. Jobs in automotive area was negatively related, however, since one was "yes" and two was "no", results should be interpreted accordingly. Persons who held jobs in

TABLE 11

REGRESSION ANALYSIS BETWEEN THE INDEPENDENT VARIABLE GROUP AND THE DEPENDENT VARIABLE ACTION CHECKS

(n = 205)

Variable	Partial Regression Coefficient	Standard Error	Student "t"
17. Group	5.5986	2.2089	2.53*
Intercept	97.23	1.5809	

Standard Error of Estimate = 15.8090

Multiple Correlation (full model) = .2905

Adjusted Coefficient of Determination (full model) = .0011

Zero Order Correlation (one independent variable) = .1751

Adjusted Coefficient of Determination (one independent variable) = .0259

$* = P < .05$

$** = P < .01$

TABLE 12

REGRESSION ANALYSIS BETWEEN FOUR INDEPENDENT VARIABLES AND THE DEPENDENT VARIABLE INFORMATION CHECKS

(n = 205)

Variables	Partial Regression Coefficient	Standard Error	Student "t"
2. Grade	3.4326	1.4743	2.33*
5. Jobs in Automotive Area	-3.6585	1.5246	2.40*
16. Engine Knowledge Test	.6114	0.1830	3.34**
17. Group	10.6467	2.1215	5.02**
Intercept	50.0214	15.7301	

Standard Error of Estimate = 15.0322

Multiple Correlation (full model) = .5118

Adjusted Coefficient of Determination (full model) = .1948

Multiple Correlation (four independent variables) = .4751

Adjusted Coefficient of Determination (four independent variables) = .2103

* = P < .05

** = P < .01

the automotive area scored on the average, 3.66 units higher on the information checks variable. Likewise, for each unit increase in engine knowledge test score there was a corresponding .6114 increase in information checks score. With regard to variable 2, a one unit increase in grade (10 to 11 or 11 to 12) reflected a corresponding 3.43 unit increase in information checks score.

The regression analysis for independent variables and the redundancy variable is provided in Table 13. Two variables, occupation knowledge and group, maintained enough uniqueness to remain in the model. Elimination of the other variables allowed the coefficient of determination to increase only slightly from .0618 to .0389. The resultant multiple correlation was moderate at .2198. This analysis may be interpreted as follows. On the average, the treatment group scored 4.69 units higher with regard to redundancy than did the non-treatment group. This meant the treatment group was less redundant at troubleshooting than the non-treatment group. With regard to occupation knowledge, a one unit increase in this score would be accompanied by a .7359 increase in redundancy score.

MRA data for the dependent variable efficiency is given in Table 14. Seven variables were significant and remained in the model. These included age, grade, outside school troubleshooting experience, jobs in automotive area, engine knowledge, group, and school B membership. The overall coefficient of determination was .2316 while, with the eleven variables removed from the model, an increase to .2509 was noted. This reflected a multiple correlation for the restricted model of .5259. Group membership again attained the highest _t_ value (5.03) which was

TABLE 13

REGRESSION ANALYSIS BETWEEN TWO INDEPENDENT VARIABLES AND THE DEPENDENT VARIABLE REDUNDANCY

(n = 205)

Variables	Partial Regression Coefficient	Standard Error	Student "t"
13. Occupation Knowledge Test	.7359	.2751	2.68**
17. Group	4.6[illegible]92	2.1930	2.14*
Intercept	91.4478	2.8524	

Standard Error of Estimate = 15.5201

Multiple Correlation (full model) = .3742

Adjusted Coefficient of Determination (full model) = .0618

Multiple Correlation (two independent variables) = .2198

Adjusted Coefficient of Determination (two independent variables) = .0389

* = $p < .05$

** = $p < .01$

TABLE 14

REGRESSION ANALYSIS BETWEEN SEVEN INDEPENDENT VARIABLES AND THE DEPENDENT VARIABLE EFFICIENCY

(n = 205)

Variables	Partial Regression Coefficient	Standard Error	Student "t"
1. Age	-.3088	0.1251	2.47*
2. Grade	6.0306	2.0088	3.00**
4. Outside School Trouble-shooting Experience	-5.1534	2.2708	2.27*
5. Jobs in Automotive Area	-3.9942	1.4904	2.67**
16. Engine Knowledge Examination	0.5269	0.1817	2.90**
17. Group	10.3764	2.0629	5.03**
21. School B Membership	4.6498	2.2150	2.10*
Intercept	91.8773	19.6204	

Standard Error of Estimate = 14.3946

Multiple Correlation (full model) = .5437

Adjusted Coefficient of Determination (full model) = .2316

Multiple Correlation (seven independent variables) = .5259

Adjusted Coefficient of Determination (seven independent variables) = .2509

* = P < .05

** = P < .01

significant beyond the .01 level. Therefore, on the average, treatment group students scored 10.38 efficiency score units above their non-treatment counterparts. This was with the effect of all other variables held constant. Additionally, school B students averaged 4.65 efficiency score units higher than did students in other schools. Likewise, the independent variable experience was related to this criterion variable. Youngsters who had outside school troubleshooting experience or had held jobs in the automotive area averaged higher efficiency scores than those who did not have these experiences. An interesting observation can be made relative to both age and grade variables. An increase in age reflected a corresponding decrease in efficiency score. Grade, however, was related in a positive manner. That is, every unit increase in grade was accompanied by a corresponding 6.03 increase in efficiency score. It may be that some older students in each grade had stayed back in school and might not be as bright, whereas, a general increase in efficiency from 10th to 11th to 12th grade could still be observed.

Relationships Between Student Characteristics the Learning of Troubleshooting via Dynamic Simulation

Concern about student characteristics as they might relate to troubleshooting performance led to an examination of this particular area. Subsequently, data for those students who received simulator instruction were analyzed separately from total sample data. As part of this analysis, three variables were included which had relevance to the simulator group. They consisted of attitude toward instruction, time to complete instruction, and time lapse between end of instruction and testing. Completion time was specified in minutes while time lapse was recorded in days.

Table 15 provides zero order correlations for the dependent and independent variables. As noted in the table, several relationships were significant at or beyond the .05 level. Correlations ranged from .418 to -.281. It should be noted that there were no significant zero order correlations between independent variables and the dependent variables search time, action checks, and redundancy. Since relationships were not significant for these three variables and subsequent regression analyses were likewise non-significant, only analyses for proficiency, information checks, and efficiency variables have been included. F-ratios for both full and restricted models with these three variables were significant beyond the .05 level.

Table 16 reports the regression analysis between two independent variables and the dependent variable proficiency. These variables, occupation knowledge and engine knowledge, each had a unique and significant relationship with the proficiency criterion. Elimination of nineteen variables increased the adjusted coefficient of determination from .1877 to .2222. The multiple correlation in the restricted model was .4879. Occupation and engine knowledge were then found to be most useful in predicting troubleshooting proficiency for the treatment group.

Regression analysis between two independent variables and the information checks variable is given in Table 17. Elimination of less useful variables from the model produced slight increase in predictive efficiency. The adjusted coefficient of determination increased from .089 to .120 and the multiple correlation in the restricted model was

TABLE 15

ZERO ORDER CORRELATIONS BETWEEN THE SIX PERFORMANCE VARIABLES AND THE INDEPENDENT VARIABLES FOR THE TREATMENT GROUP
(n = 99)[a]

Variables	Proficiency	Search Time	Action Checks	Information Checks	Redundancy	Efficiency
1. Age	.218*	.011	.160	.201*	-.011	.170
2. Grade	.223*	-.033	.095	.284**	.134	.299**
3. School Troubleshooting Experience	-.281**	.068	-.095	-.225*	-.064	-.229*
4. Outside School Troubleshooting Experience	-.215*	.106	-.031	-.211*	-.111	-.236*
5. Jobs in Automotive Area	-.178	.175	-.003	-.248*	-.180	-.270**
6. Hobbies in Automotive Area	-.008	.037	.096	.072	-.098	.018
7. Employment in Home Area	-.123	-.023	-.054	-.052	-.103	-.046
8. Father's Occupation	.049	.102	.131	.015	-.156	-.058
9. Instruction Attitude Inventory	.033	-.068	.032	.094	.110	.087
10. Time Lapse - Instruction and Test	.017	.09[illegible]	.003	-.095	-.058	-.101
11. Time to Complete Instruction	-.123	.079	.059	-.070	-.070	-.127
12. School Motivation Scale	-.149	.008	-.030	-.158	-.149	-.187
13. Occupation Knowledge Test	.395**	-.182	.012	.247*	.187	.299**
14. CTMM Language	.042	-.024	.030	.238*	.059	.255*
15. CTMM Non-Language	.156	.071	.099	.262**	.046	.252*
16. Engine Knowledge Test	.418**	-.080	.071	.305**	.114	.307**
17. Group	.000	.000	.000	.000	.000	.000
18. School A Membership	.111	.043	.015	.063	.055	-.122
19. School B Membership	.170	.070	.104	.019	.095	.023
20. School C Membership	.000	.009	.026	.048	.110	-.052
21. School D Membership	.080	.049	.037	.168	.090	.188

[a]Six persons were eliminated from the treatment group because of missing data for variables 9, 10, or 11.

* = P < .05

** = P < .01

TABLE 16

REGRESSION ANALYSIS BETWEEN TWO INDEPENDENT VARIABLES AND THE DEPENDENT VARIABLE PROFICIENCY

(n = 99)

Variables	Partial Regression Coefficient	Standard Error	Student "t"
13. Occupation Knowledge Test	.0451	.0160	2.82**
16. Engine Knowledge Test	.0334	.0104	3.22**
Intercept	.4692	.2297	

Standard Error of Estimate = .5575

Multiple Correlation (full model) = .5875

Adjusted Coefficient of Determination (full model) = .1877

Multiple Correlation (two independent variables) = .4879

Adjusted Coefficient of Determination (two independent variables) = .2222

* = P < .05

** = P < .01

TABLE 17

REGRESSION ANALYSIS BETWEEN TWO INDEPENDENT VARIABLES AND THE DEPENDENT VARIABLE INFORMATION CHECKS

(n = 99)

Variables	Partial Regression Coefficient	Standard Error	Student "t"
5. Jobs in Automotive Area	-6.6583	2.9771	2.24*
16. Engine Knowledge Test	0.6839	0.2346	2.92**
Intercept	100.3772	7.8602	

Standard Error of Estimate = 14.0519

Multiple Correlation (full model) = .5155

Adjusted Coefficient of Determination (full Model) = .0892

Multiple Correlation (two independent variables) = .3714

Adjusted Coefficient of Determination (two independent variables) = .1200

* = P < .05

** = P < .01

.3714. Two variables, jobs in automotive area and engine knowledge test, attained _t_ values which were significant beyond the .05 and .01 levels respectively. These variables were identified as being unique predictors of "information checks" troubleshooting performance.

Table 18 presents regression analysis between five independent variables and the dependent variable efficiency. The five variables which reflected a unique relationship with efficiency included jobs in automotive area, attitude toward instruction, motivation toward schoolwork, occupation knowledge, and non-language ability. Precision in prediction was gained by eliminating less useful variables. The adjusted coefficient of determination increased from .1609 to .2108 with a multiple correlation of .5010. Thus, one experience, two affective and two cognitive type variables were unique predictors of troubleshooting efficiency for the treatment group.

Students' Attitudes Toward Dynamically Simulated Troubleshooting Instruction

Attitude Measurement

The measurement of attitudes is, perhaps, one of the most difficult tasks facing an educational researcher. This situation is confounded by the fact that we know so little about relationships between attitude and subsequent behavior.

Does a positive attitude toward instruction reflect greater achievement in that instruction? Assuming (for the present) that this is generally true, it is then in order to examine how attitude varies as a function of different instructional environments. In this particular investigation student attitude toward simulated troubleshooting instruction was descriptively compared with student attitude toward different

TABLE 18

REGRESSION ANALYSIS BETWEEN FIVE INDEPENDENT VARIABLES AND THE DEPENDENT VARIABLE EFFICIENCY

(n = 99)

Variables	Partial Regression Coefficient	Standard Error	Student "t"
5. Jobs in Automotive Area	-6.6832	2.8258	2.36*
9. Instruction Attitude Inventory	0.1428	0.0670	2.13*
12. School Motivation Scale	-0.9965	0.3586	2.78**
13. Occupation Knowledge Test	0.8022	0.3469	2.31*
15. CTMM Non-Language	0.5134	0.1943	2.64*
Intercept	83.8314	14.3744	

Standard Error of Estimate = 13.1219

Multiple Correlation (full model) = .5688

Adjusted Coefficient of Determination (full model) = .1609

Multiple Correlation (five independent variables) = .5010

Adjusted Coefficient of Determination (five independent variables) = .2108

* = P < .05

** = P < .01

instruction in different instructional environments. These environments consisted of classroom or theory instruction which was taught more on a group basis and shop instruction which was given on a somewhat individual basis. The measure of student attitude was The Instruction Attitude Inventory.

Students' Attitudes

For comparative purposes, several groups of students were identified as being similar in terms of relative age and instructional major. The students were asked to fill out the Instruction Attitude Inventory (IAI) after they had completed their various instructional sequences. The three automotive groups consisted of:

A. 113 automotive students reacting to classroom instruction received from six instructors (30 to 60 minutes instruction).

B. 93 automotive students reacting to shop instruction received from four instructors (2-1/2 to 3 hours instruction).

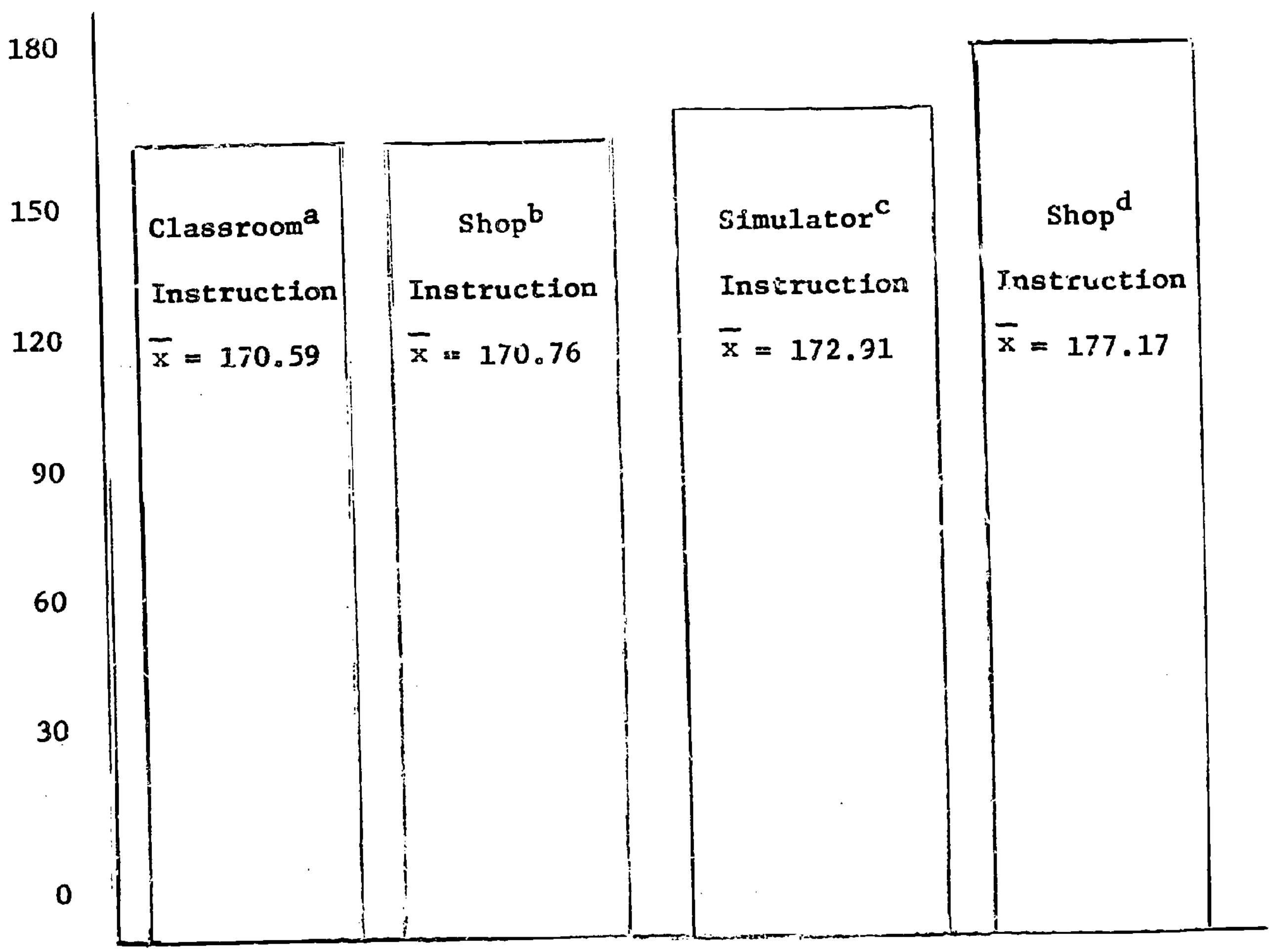
C. 119 automotive students reacting to troubleshooting instruction received individually on the simulator (average of approximately five hours instruction).

A fourth group was comprised of 245 students from twenty vocational areas reacting to shop instruction received from approximately fifteen instructors (2-1/2 to 3 hours instruction). This group was included to provide an additional attitude "base line".

Mean scores for the four groups are presented in Figure 2. As the scores indicate, automotive students' attitudes toward simulator instruction were at least as favorable as other students attitudes toward traditional classroom and shop instruction. There was no appreciable difference between the mean scores for the groups. Likewise,

FIGURE 2

STUDENT ATTITUDE TOWARD SIMULATOR INSTRUCTION AS COMPARED WITH STUDENT ATTITUDE TOWARD DIFFERENT INSTRUCTION IN DIFFERENT INSTRUCTIONAL ENVIRONMENTS



[a]113 automotive students reacting to classroom instruction received from six instructors (30-60 minutes of instruction).

[b]93 automotive students reacting to shop instruction received from four instructors (2-1/2 - 3 hours of instruction).

[c]119 automotive students reacting to simulator instruction received (average of approximately five hours instruction).

[d]245 students from twenty vocational areas reacting to shop instruction received from approximately 15 instructors (2-1/2 - 3 hours of instruction).

very little difference existed between students' attitudes toward simulator instruction and other students' attitudes toward shop instruction in a number of vocational course areas. The results appear to be stable in that groups were not different to any great extent in terms of variability. Standard deviations for the groups are as follows:

Automotive Classroom Instruction - 20.79
Automotive Shop Instruction - 20.10
Simulator Instruction - 21.33
Multi-Area Shop Instruction - 25.37

An additional comment should be made relative to the instrument that was used. The IAI has a possible range of 47 to 235. That is, students who were completely negative about the instruction would receive a score of 47 while students having completely positive attitudes toward the instruction would receive a score of 235. Even though students had the option to react in a very negative manner they chose, as groups, to react positively to simulator, classroom and shop instruction.

Teachers' Perceptions of Troubleshooting Instruction Via Dynamic Simulation

A total of eight instructors provided their reactions to the Simulator Evaluation Questionnaire in this study. All were currently teaching automobile mechanics and had been given their students troubleshooting instruction on the simulator. Even though group size can be considered small, the results should have some generalizability. As part of the study, the instructors were required to use the simulator in a similar manner at all locations. This meant that instructors reacted to common experiences. Additionally, the instructor group evaluated the same instructional hardware and software in the same teaching environment. Therefore, results were not unnecessarily confounded by reactions to different instructional approaches or content.

How then did instructors perceive simulator effectiveness in a vocational school setting? Composite instructor responses are provided in Appendix A. It should be noted that, with such a small group, the responses indicate trends and will be reported accordingly.

Motivation (items 36 and 55). The instructor group unanimously felt that the simulator was a positive motivator for their students. All instructors either agreed or strongly agreed the simulator created interest among their students and that it gave students more confidence in performing troubleshooting activities.

Realism (items 10, 25, 42 and 53). The instructor group seemed generally pleased with the realism which the simulator conveyed. Six of eight persons felt that basic troubleshooting skills could be taught with the simulator as well as or better than with actual equipment. The other two instructors felt that actual equipment was better for teaching basic troubleshooting skills. All instructors agreed that simulator panels portray the various systems in a realistic manner and that the simulator program is very close to reality. Seven of the eight instructors felt that a student can learn systematic diagnosis of problems with the simulator.

Facilitation of Instruction (items 26, 27, 41, 51, 52, 57, 59, 60 and 61). Items relating to facilitation of instruction were generally concerned with ease of simulator operation and the use of instructional time as compared with that afforded by more conventional instruction.

Instructors unanimously agreed that it is easy to switch the simulator's various instructional panels and that problems can be repeated simply and without much time involved. Additionally, all persons felt that, with the simulator, more problems can be demonstrated in a shorter period of time. The eight instructors disagreed with the statement that it is easier to use actual equipment for troubleshooting instruction rather than use the simulator. The instructor group was split half and half (four disagreed and four agreed) on the statement that only a limited number of problems can be placed into the simulator. A similar break was noted with item 57 which specified "learning time is cut in half when using the simulator." Four persons disagreed with the statement while three agreed and one strongly agreed. Regarding instructor contact time in a more specific manner, the group agreed unanimously that, by using the simulator, a teacher is allowed time to carry on other activities. Likewise, seven persons felt that students need little supervision when they are on the simulator. An eighth person disagreed with this statement. Finally, six of the eight instructors agreed that it takes a great deal of time to teach each student with the simulator but less than by other means.

Transfer (items 2, 45, and 49). Simulator effectiveness can also be ascertained in terms of the extent to which it provides transfer to other instruction or to ultimate program objectives. The instructors were in unanimous agreement (six strongly agreed and two agreed) that "the simulator provides my students with a good way to learn troubleshooting skills." A majority of the group felt that the simulator helps students to diagnose customers' complaints (five agreed or strongly agreed while one disagreed and one strongly disagreed). A majority of the group (five) agreed that a few of the simulator problems were hard to transfer to actual equipment. Three persons disagreed with this statement.

Maintainability (items 1, 6, 20, 24, 43, and 48). This particular area focused on the teacher's perceptions of simulator reliability and company service. A majority of the instructors disagreed with the statement that company service on the simulator was poor. However, with regard to the actual unit, five of the eight instructors agreed that the simulator requires a great deal of maintenance. Three instructors felt that simulator break-down did not occur very frequently while five persons were in disagreement with this statement. The same pattern of responses occured with the statement "it is relatively easy to maintain the simulator." It is interesting to note, however, that six of the eight instructors felt component parts of the simulator are somewhat reliable. In terms of continued efforts in this area, six instructors agreed or strongly agreed that they should receive more information on how to maintain the simulator.

Enhancement of the Learning Process (items 16, 18, 22, 38, 46, 47, 50, 54, and 56). A concern of this area was with the ways in which the simulator enhances or detracts from student learning. All instructors felt that the simulator allows a student to work at his own pace. Seven of the eight agreed that the student thinks for himself when he is working with the simulator (four of the seven strongly agreed). Likewise, seven persons felt the simulator gives students a pattern to follow when solving a particular problem. Six instructors disagreed with the statement "It is difficult to tell how much a student has learned from his simulator instruction." With regard to strategies for learning several statements have particular relevance. Seven of the eight instructors agreed that students should work on the simulator by themselves. Moreover, all eight unanimously agreed that, after a student has completed simulator instruction, his troubleshooting performance should be evaluated and that the handbook used with the simulator was easy to follow. A final point should receive consideration when instructing youngsters with varying abilities; six of the eight instructors agreed that students who did not understand the simulator instruction tended to skip over it.

Availability and Mobility (items 34, 40 and 58). This area dealt with the logistics of simulator use in an instructional setting. Instructors were split half and half regarding the statement "It is relatively easy for several instructors to coordinate the time that they will use the simulator with their respective classes." Four agreed or strongly agreed while four others disagreed or strongly disagreed. Another split was found relative to mobility. Four teachers felt that the simulator was not very mobile while four others disagreed with this statement. Last, five persons agreed that the unit was easy to move while three others disagreed on this point.

Instruction (items 12, 13, 17, 19, 21, 23, 30, 39, and 44). This particular area dealt with the simulator as it relates to the instructional environment. The instructors were in unanimous agreement that the simulator is a useful instructional device (four agreed and four strongly agreed). They all disagreed with the statement "the simulator does not fit well into my vocational program." A more specific item (number 23) stated that "the simulator provides students with a good transition from classroom (theory) instruction to troubleshooting actual equipment." All persons responding to this item either agreed or strongly agreed with it. Seven of the eight instructors disagreed with the statement "simulator instruction is not any better than troubleshooting instruction I have been providing in the past" while five of seven responding to "The simulator dehumanized vocational education" disagreed with it. Seven of the eight instructors felt that they could make good instructional use of the simulator anytime that it is available. Two additional statements dealt with individualized instruction. All instructors felt that the simulator is good for individualized instruction while six of the eight disagreed with the statement "The simulator is more meaningful as a classroom aid than as a unit for individualized instruct[illegible]

[illegible] (items 3, 4, 5, 7, 8, 9, 11, 14, 15, 28, 29, 31, 32, 33, 35, and 37). A last area was directed primarily toward future utilization of the simulator. In general, the instructors felt that students should work on the simulator individually, in an area which is relatively quiet and where they cannot be bothered by other students. They seemed to feel that the unit might be located both in the classroom and the shop area. With regard to instructional time it was generally agreed that the optimum would be with students scheduled on the simulator for periods ranging from one to two hours. Instructors generally felt that the research project did not interfere with day to day teaching activities and that students were not bothered greatly by the simulator evaluation. A final group of items focused on software (i.e., written materials used to compliment simulator instruction). The instructors generally agreed that the simulator should be used in conjunction with written materials such as booklets and instruction sheets and that these materials should be utilized when basic and advanced troubleshooting instruction is being given. Seven of the eight instructors felt that they should be provided with time to develop instructional materials that can be used with the simulator.

IV

CONCLUSIONS AND IMPLICATIONS

Based upon the findings which have been presented, there are a number of conclusions that may be drawn and several implications for vocational educators. The discussion which follows attempts to synthesize results of the research project in a logical manner. It should be remembered, however, that comments have been based upon this particular project with its own limitations. Generalizations developed from this study should be made while keeping the foregoing in mind.

Conclusions

The general effectiveness of dynamic simulation as a means of teaching troubleshooting was examined using a treatment group and a non-treatment group. Multiple regression analysis revealed that, when other variables were held constant, the treatment group performed significantly better than the non-treatment group with regard to four of the six criterion measures. The treatment group made [illegible] checks and more information checks. Additionally, this group was less redundant and more efficient than the non-treatment group. It should be noted that the four criteria which differentiated between treatment and non-treatment were task procedure measures rather than task end product measures (Finch and Impellitteri, 1971). That is, they could be associated with the troubleshooting search process rather than with the result of this process. It is, therefore, contended that the simulator is most useful in terms of teaching meaningful troubleshooting strategies. In the present study, this instruction was provided in conjunction with appropriate software (programed materials). The extent to which troubleshooting strategy development can take place without supporting materials was beyond the scope of the investigation, however, it may well be that teacher-student interaction on an individual basis could be equally as effective as programed material use. Future research efforts might be directed in this area.

A comment should be made regarding the troubleshooting performance measures which were selected for use in this study. Proficiency was specified categorically (1, 2, or 3) and, consequently, was limited in terms of variability. This condition, coupled with problem difficulty, may have contributed to the lack of difference between groups. Search time was included as a criterion because of the traditional contention that time is a meaningful measure of performance. This variable was not a measure of time to reach solution but time spent searching for problem solution. The search time variable then initially appeared to be questionable and remained questionable since it did not differentiate between groups.

In order to examine the relationships between student characteristics and the learning of troubleshooting via dynamic simulation, regression analysis was conducted for those youngsters who had received simulator instruction. Findings indicated that significant relationships existed between certain independent variables and three of the six performance measures. These criteria included proficiency, information checks, and efficiency. Occupation and engine knowledge were unique predictors of troubleshooting proficiency, whereas, holding a job or jobs in the automotive area and engine knowledge were predictive of troubleshooting information gathering performance. A number of variables were unique predictors of troubleshooting efficiency. These included job held in automotive area, attitude toward the instruction received, motivation toward schoolwork, occupation knowledge, and non-language ability. It is interesting to note that no one variable was consistantly predictive of performance across the three criterion measures. Engine knowledge and occupation knowledge variables were predictors for two of the three performance criteria with both being significantly related to proficiency. In addition, the traditionally strong predictor of performance (verbal ability) was not significantly related to any of the troubleshooting performance criteria. It appears that, when students are being selected to be involved with simulator instruction, consideration should be given to prior job experience, motivation toward schoolwork, occupation knowledge and non-language ability if the instructional outcome is specified as increased troubleshooting efficiency. If proficiency performance is to be maximized, students should be selected on the basis of occupation knowledge and specific equipment (in this case engine) knowledge. Last, with regard to selecting those students who will perform best at information gathering, student job experience and specific equipment knowledge should be examined.

Based upon the results regarding instructor reactions to the simulator, several conclusions can be developed. First, the teacher group appeared to feel that the simulator was an effective instructional device for teaching troubleshooting. They additionally felt that the simulator motivated students in a positive manner and enhanced the learning process. Instructors generally agreed that the unit was useful in facilitating troubleshooting instruction and that it displayed operational systems in a realistic manner. The instructor group was not as favorably inclined toward simulator mobility and maintainability, however, they were genera[illegible] not unfavorably inclined. Comments relative to future utilization of the simulator were detailed in an earlier section.

With regard to student attitude toward simulator instruction, several points can be made. Although a descriptive comparison of attitudes was made, there is an obvious absence of major attitudinal differences between the group exposed to simulator instruction and other groups exposed to different instruction. It is difficult to generalize from this type of data, however, for the present, it appears that students' attitudes toward individualized simulator instruction are not radically different from their attitudes toward other instruction in other environments.

Implications

Several implications can be identified which have relevance to program improvement in vocational-technical education. First, the results should provide meaningful information to vocational educators at the state level. Since the simulator has shown utility in providing troubleshooting instruction, even to the extent of transfer to actual equipment, state planners should give serious consideration to the use of this type simulator in areas where the development of complex skills is critical. Of course, cost is an important factor. However, a small computer or piece of machinery would be comparable in cost and might not have a general purpose capability. As the project was being completed, the various schools were quick to move the simulators into other instructional areas and provide troubleshooting instruction on different systems.

Second, in order to maximize simulator use, directors and teachers would do well to specify instructional objectives and state how the simulator might aid in attaining these objectives. The unit could then be utilized in accordance with instructional priorities. Scheduling a simulator might be similar to scheduling an audio-visual aid. The result would be maximum utilization and a reduced cost per student.

A third implication focuses on student characteristics. It appears that, by providing self-paced simulator instruction, the effects of variables typically associated with low achievement (i.e. verbal ability) were minimized. Instructors should attempt to use the simulator in an individualized self-paced manner as much as practicable. In this way, certain differences among students might be held to a minimum. This, of course, does not mean that all individual differences are minimized. The instructor should be aware of student characteristics which relate to the performance described (i.e. proficiency, efficiency) and match these characteristics with specified instructional outcomes.

Last, this particular study focused on individualized troubleshooting instruction via simulation. It should in no way preclude the use of this unit in both small group and large group instruction. Although instructors generally felt that the simulator was very useful for individual instruction, the exact extent of simulator usefulness is not yet known. Instructors should take the initiative to develop materials and try out new teaching approaches using simulation. In this manner, many aspects of the learning process may be enchanced.

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APPENDIX A

MEASURING INSTRUMENTS

CONFIDENTIAL

D S S
1 2 3
0 1
4 5
6 7 8
9 10

STUDENT INFORMATION SHEET

1. Name:______________________________ 2. Date:__________ 11 12 13

3. Mailing Address:____________________________________ 14 15

4. City:__________________ State:__________ Zip:________ 16 17 18

5. Area Vocational Technical School:____________________ 19

6. Course Area (Major):______________________________ 20

7. Teacher's Name:__________________________________ 21 22

8. Birth Date: Day__________ Month__________ Year______ 23 24 25

9. Sex (circle one): Male Female 26

10. Year in school (circle one): 10 11 12 Adult 27 28

11. Have you ever had any troubleshooting experience in school? (circle one) Yes No 29

12. Have you ever had any troubleshooting experience outside of school? (circle one) Yes No 30

13. List the part-time and full-time jobs you have held:

____ 31 32 33

____ 34

14. List your hobbies:______________________________ 35

____ 36 37 38

15. How would you classify the area where you live? (circle one) Farm Town City 39

16. How would you classify the area where you live? (circle one) everyone has jobs some don't have jobs many don't have jobs 40

17. Have you ever been discriminated against? (circle one) Yes No 41

18. What is (or was) your father's occupation?______________ 42

19. How would you classify your father's occupation? (circle one) 43 44 45

Unskilled Semi-skilled Skilled
Technical Professional 46

Has your family ever been on welfare? (circle one)
Yes No 47 48 49

AUTOMOBILE ENGINE KNOWLEDGE

Name______________________________School____________________________

Date____________________ Instructor's Name____________________________

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. A condenser is charged by the collapsing field of the circuit known as

   A. secondary.
   B. ignition.
   C. generator.
   D. primary.

2. The secondary current begins to flow in the ignition coil when the

   A. condenser discharges.
   B. primary current flows.
   C. points open.
   D. points close.

3. The compressed mixture between the spark plug electrodes causes a high degree of

   A. tension.
   B. resistance.
   C. conductance.
   D. combustibility.

4. An ignition coil increases battery voltage by principles of

   A. constant-potential.
   B. non-conduction.
   C. polarization.
   D. electromagnetism.

5. The ignition condenser discharges into the

   A. secondary circuit.
   B. primary circuit.
   C. ground circuit.
   D. radio circuit.

6. The greatest amount of electrical pressure is required to

   A. crank engine starter.
   B. jump gap between rotor and distributor cap.
   C. saturate coil primary winding.
   D. jump spark gap in engine under load.

7. The centrifugal advance controls ignition timing in relation to

   A. load.
   B. speed.
   C. fuel.
   D. mileage.

8. The main function of the ignition condenser is to produce

   A. slow magnetic collapse.
   B. quick magnetic collapse.
   C. high voltage on points.
   D. a spark on the plugs.

9. Ignition point bounce at high speed is likely to be caused by

   A. excessive spark advance.
   B. shorted condenser.
   C. excessive point spring pressure.
   D. low point spring pressure.

10. A cracked distributor cap will cause

   A. burned contacts.
   B. the rotor to break.
   C. primary resistance.
   D. cross firing.

11. The magnetic field is produced in a starter by the use of

   A. artificial magnets.
   B. electromagnets.
   C. bar magnets.
   D. nichrome resistors.

12. When a circuit is to be tested, the ammeter is connected in

   A. parallel.
   B. series-parallel.
   C. series.
   D. shunt-series.

13. When a circuit is to be tested, the voltmeter is connected in

A. parallel.
B. series.
C. shunt-series.
D. parallel-series.

14. To force the same amount of current through two wires of the same diameter when one is longer than the other, the longer one requires

A. more voltage.
B. less voltage.
C. more amperage.
D. less amperage.

15. If the resistance increases and the voltage remains the same, the amperage will

A. drop.
B. rise.
C. remain the same.
D. fluctuate.

16. Current flow through circuits may be greatly decreased by

A. too many connections.
B. sharp turns in wires.
C. heavy insulation.
D. terminal resistance.

17. The hydrometer is used to

A. measure battery capacity.
B. check specific gravity.
C. measure battery water.
D. measure the acid.

18. A more accurate hydrometer test is made when the

A. cell temperature is considered.
B. hydrometer is held horizontally.
C. solution is high.
D. bulb is completely released.

19. The purpose of a venturi in a carburetor is to increase air

A. volume.
B. velocity.
C. resistance.
D. impedance.

20. The purpose of the pump system in a carburetor is to

A. prevent lean mixture on acceleration.
B. serve as an emergency pump.
C. enrich the mixture for pulling.
D. pump gas to the float bowl.

21. The function of the idle metering screw is to

A. vary the amount of fuel from the bowl to the low speed jet.
B. control the suction to the economizer.
C. vary the amount of idle mixture entering the manifold.
D. adjust the throttle for smooth idling.

22. When the engine is operating at normal temperature the automatic choke

A. spring is expanded.
B. valve is closed.
C. shaft is locked.
D. valve is wide open.

23. The fuel pump is operated by the

A. crankshaft.
B. camshaft gear.
C. camshaft.
D. distributor gear.

24. Which of the following is a part of the cranking system?

A. battery
B. generator.
C. alternator.
D. regulator.

25. The starting motor takes electrical energy and converts it to

A. work pounds.
B. horsepower.
C. mechanical energy.
D. linear motion.

26. Which of the following is <u>not</u> contained in a starting motor?

A. armature.
B. pole pieces.
C. drive mechanism.
D. alternator.

27. Which of the following would cause a starting system to be faulty?

A. open circuit breaker.
B. open ignition switch circuit.
C. shorted alternator circuit.
D. shorted battery ground terminal.

28. 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.

29. 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.

30. Where does the ignition circuit release its high-voltage charge?

A. coil.
B. rotor.
C. condenser
D. spark plug.

31. For the engine to run faster, when must the spark fire?

A. earlier.
B. later.
C. intermittently.
D. about the same.

32. Which of the following is <u>not</u> part of an electrical circuit?

A. conductor.
B. initiator.
C. load device.
D. power source.

33. What surrounds the secondary winding of the coil?

A. coil core.
B. primary winding.
C. distributor cap.
D. high tension leads.

34. What is the primary purpose of the vacuum advance mechanism?

A. increase power.
B. increase current.
C. increase plug life.
D. increase gas mileage.

35. Which of the following is <u>not</u> a part of the ignition system?

A. coil.
B. battery.
C. generator.
D. distributor.

36. What does the spark ignite in the combustion chamber?

A. gasoline.
B. compression.
C. spark plug.
D. gas-air mixture.

37. 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.

38. What supplies the initial power for cranking and ignition?

A. coil.
B. battery.
C. condenser.
D. generator.

39. How many lobes are on the breaker cam of a four cylinder engine?

A. two.
B. four.
C. six.
D. eight.

40. What is the name of the pressure that moves the current in an electrical circuit?

A. voltage.
B. amperage.
C. resistance.
D. electricity.

4_. What material makes up the core of an ignition coil?

A. iron.
B. steel.
C. copper.
D. aluminum.

42. What is the opposition to current flow called?

A. voltage.
B. amperage.
C. wattage.
D. resistance.

43. Which of the following are always contained in a magnetic field?

A. resistors.
B. conductors.
C. coils of wire.
D. lines of force.

44. 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.

45. Which of the following stops current for a fraction of a second?

A. coil.
B. resistor.
C. condenser.
D. alternator.

46. What controls basic timing of the spark to the engine cylinder?

A. coil.
B. rotor.
C. timing light.
D. distributor shaft.

SCHOOL MOTIVATION SCALE

Name________________________ School________________________

Date________________ Instructor's Name________________________

DIRECTIONS: Indicate how you feel about the statements below by marking an X in the appropriate column.

		YES	NO
1.	Students should set their goals only as high as they can easily reach...	[ ]	[ ]
2.	Does it bother you if another student makes better grades than you do?...	[ ]	[ ]
3.	Would you rather be a leader in a small school than to be just another student in a large school?......................	[ ]	[ ]
4.	Does failure discourage you from trying as hard the next time?...	[ ]	[ ]
5.	You should select your friends from among those whose goals are generally as high as your own......................	[ ]	[ ]
6.	Would you like to take a school subject in which no tests were to be given?...	[ ]	[ ]
7.	Do you often compare your work with the work of others?......	[ ]	[ ]
8.	Are you usually on time with written assignments?............	[ ]	[ ]
9.	Do you believe, "Win or lose, who cares?"......................	[ ]	[ ]
10.	Do you try to make better grades than other students in your classes?...	[ ]	[ ]
11.	Rewards should be given regardless of effort or achievement...	[ ]	[ ]
12.	Would you, or do you, enjoy being one of the class leaders?...	[ ]	[ ]
13.	The person who makes the highest grade on a test is to receive an award. Would you stay home from a social event or an athletic contest to study?............................	[ ]	[ ]
14.	Do you stick to an assignment until it is completed even though it is dull and boring to you?........................	[ ]	[ ]

		YES	NO
15.	If you lost several times consecutively, would you quit trying?	[ ]	[ ]
16.	Would you prefer to enroll in a course in which no grades are to be given?	[ ]	[ ]
17.	Would you ever enter a contest with other students knowing you had a very slight chance of winning?	[ ]	[ ]
18.	Do you think that school letters should be given for high grades as well as for football and basketball?	[ ]	[ ]
19.	If you had to choose between taking part in a contest or being one of the judges, would you choose to be a judge?	[ ]	[ ]
20.	Do you think that you enjoy trying to do well in your school subjects more than other boys and girls in your classes?	[ ]	[ ]
21.	Would you prefer to sit in the back of a classroom?	[ ]	[ ]
22.	Rewards earned are worth more than those which come without effort	[ ]	[ ]
23.	The more people who seek the same goal the harder you try for it	[ ]	[ ]
24.	What parents expect of their children is more important than what the child wants for himself	[ ]	[ ]
25.	Your friend stopped running when it became evident that he was losing the race. Would you have stopped running in this situation?	[ ]	[ ]
26.	Do you tell your parents about your successes?	[ ]	[ ]
27.	Do you tell your parents about your failures?	[ ]	[ ]
28.	When someone is being praised do you wish you were?	[ ]	[ ]
29.	When someone else is praised does it cause you to give less effort?	[ ]	[ ]
30.	Is there someone you enjoy beating in a contest or in school grades?	[ ]	[ ]

STUDENT REACTION FORM

Name____

School______________________________________

1. What did you like best about your instruction on the SMART trainer? Write two or three things which you liked best about this instruction.

2. What did you like least about your instruction on the SMART trainer? Write two or three things which you liked least about this instruction.

NAME______________________________ DATE______________________________

STUDENT INSTRUCTIONS FOR THE TROUBLESHOOTING PERFORMANCE EVALUATION

This evaluation is designed to find out how well you can troubleshoot an automobile engine. You will try to find two troubles which have been placed in an engine one at a time. It will be your job to find each trouble using the procedure and checks which were learned in your automotive instruction. No charts or books may be used to help you, however, you may use the tools provided by the instructor. After the exam has started, you may not talk unless the instructor asks you a question. The indication for each trouble is "the car will not start."

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

1. Use the procedure and sequence that was taught in your automotive instruction.
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.
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 ______________________________

NOTE: PLEASE DO NOT DISCUSS THIS EVALUATION WITH OTHER STUDENTS. TO DO SO MAY LOWER YOUR SCORE. THANK YOU.

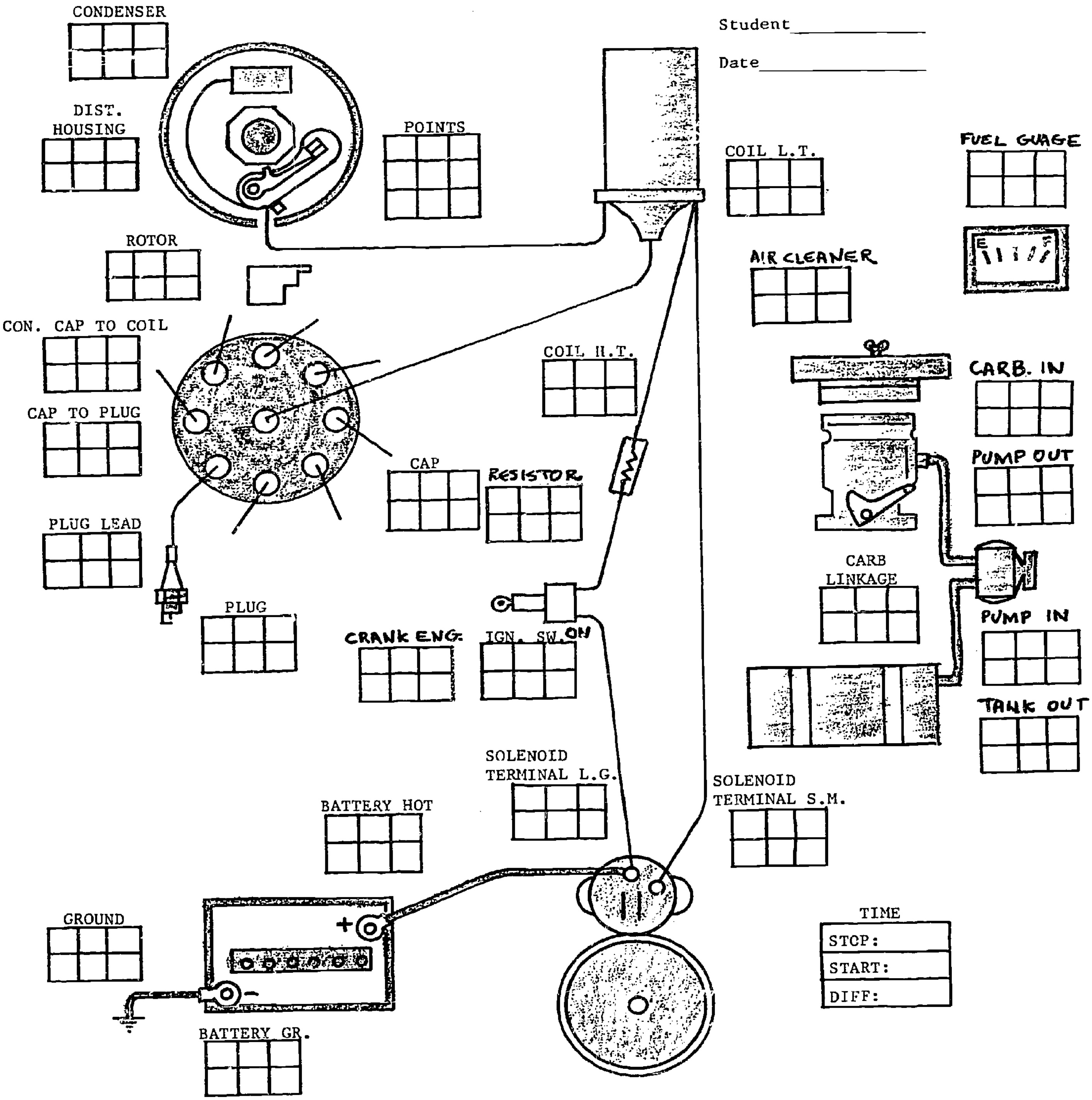
After you are sure that you understand these instructions, tell the instructor that you are ready and he will start.

RECORD OF TROUBLESHOOTING
BEHAVIOR

Test No.__________

Student__________

Date__________



The Pennsylvania State University • Department of Vocational Education • Instruction Attitude Inventory (IAI)

AST NAME FIRST INITIAL DATE

OURSE INSTRUCTOR

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

SD = STRONGLY DISAGREE D = DISAGREE N = NEUTRAL A = AGREE SA = STRONGLY AGREE

USE A # 2 PENCIL FOR MARKING. DO NOT USE BALL POINT PEN OR RED PENCIL. ERASE ALL UNINTENDED MARKS.

	SD	D	N	A	SA
I would like more instruction presented in this way....					
I learned more because equipment was available for me to use					
This instruction was very boring					
The material presented was of much value to me					
The instruction was too specific					
I was glad just to get through the material					
The material presented will help me to solve problems					
While taking this instruction I almost felt as if someone was talking with me					
I can apply very little of the material which I learned to a practical situation					
The material made me feel at ease					
In view of the time allowed for learning, I felt that too much material was presented					
I could pass an examination over the material which was presented					
I was more involved with using equipment than with understanding the material					
I became easily discouraged with this type of instruction					
I enjoy this type of instruction because I get to use my hands					
I was not sure how much I learned while taking this instruction					
There are too many distractions with this method of instruction					
The material which I learned will help me when I take more instruction in this area					
This instructional method did not seem to be any more valuable than regular classroom instruction					
I felt that I wanted to do my best work while taking this instruction					
This method of instruction makes learning too mechanical .... (SD D A N SA)					
The instruction has increased my ability to think					
I had difficulty reading the written material that was used					
I felt frustrated by the instructional situation					
25. This is a poor way for me to learn skills					
26. This method of instruction does not seem to be any better than other methods of instruction					
27. I am interested in trying to find out more about the subject matter					
28. It was hard for me to follow the order of this instruction					
29. While taking this instruction I felt isolated and alone....					
30. I felt uncertain as to my performance in the instruction ..					
31. There was enough time to learn the material that was presented					
32. I don't like this instruction any better than other kinds I have had					
33. The material presented was difficult to understand					
34. This was a very good way to learn the material					
35. I felt very uneasy while taking this instruction					
36. The material presented seemed to fit in well with my previous knowledge of the subject					
37. This method of instruction was a poor use of my time ...					
38. While taking this instruction I felt challenged to do my best work					
39. I disliked the way that I was instructed					
40. The instruction gave me facts and not just talk					
41. I guessed at most of the answers to problems					
42. Answers were given to the questions that I had about the material					
43. I seemed to learn very slowly with this type of instruction					
44. This type of instruction makes me want to work harder...					
45. I did not understand the material that was presented					
46. I felt as if I had my own teacher while taking this instruction					
47. I felt that no one really cared whether I worked or not ...					

A 0 1 2 3 4 5 6 7 8 9 B 0 1 2 3 4 5 6 7 8 9

DC 7673

INSTRUCTOR REACTION FORM

Name____

School______________________________________

1. As an instructor, what do you like best about the simulator? List three or four things that you like best about the simulator.

2. As an instructor, what do you like least about the simulator? List three or four things that you like least about the simulator.

SIMULATOR EVALUATION QUESTIONNAIRE

Name_______________________________ School ______________________________

DIRECTIONS: Below are several statements about the simulator (SMART) which you have been using with your classes. Read each statement carefully and indicate the extent 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.

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	Agree	Strongly Agree
1. The simulator requires a great deal of maintenance		3	5	
2. The simulator provides my students with a good way to learn troubleshooting skills			2	6
3. The simulator should be used in conjunction with instructional materials such as booklets and instruction sheets		1	3	4
4. The simulator should be located in the classroom		1	4	3
5. The simulator should be used instead of classroom troubleshooting instruction	3	2	2	
6. Simulator break-downs did not occur very frequently	1	4	3	
7. The simulator should be located in the school shop area		3	1	4
8. Instructors should be provided with time to develop instructional materials that can be used with the simulator		1	3	4
9. Students should work on the simulator in groups	2	5	1	

	Item	Strongly Disagree	Disagree	Agree	Strongly Agree
10.	Basic troubleshooting skills can be taught better on actual equipment than on the simulator.........		6	2	
11.	Evaluation of the simulator interferred with day to day teaching activities......................		6	2	
12.	The simulator is a useful instructional device....			4	4
13.	I can make good instructional use of the simulator anytime that it is available.......................		1	2	5
14.	Students should be scheduled on the simulator for periods of time ranging from 15 to 30 minutes.....		5	2	1
15.	Students should be scheduled on the simulator for periods of time ranging from 1 to 2 hours.........		2	6	
16.	Students should work on the simulator by themselves		1	5	1
17.	My personal experiences in preparing to teach with the simulator have helped me to learn more about troubleshooting................................		2	4	2
18.	After a student has completed simulator instruction, his troubleshooting performance should be evaluated..			7	1
19.	The simulator does not fit well into my vocational program................................	6	2		
20.	Instructors should receive more information on how to maintain the simulator.....................	1	1	3	3
21.	Simulator instruction is not any better than troubleshooting instruction I have been providing in the past................................	1	6	1	
22.	It is difficult to tell how much a student has learned from his simulator instruction............		6	2	
23.	The simulator provides students with a good transition from class room (theory) instruction to troubleshooting actual equipment................			4	3
24.	It is relatively easy to maintain the simulator...	1	4	3	

	Strongly Disagree	Disagree	Agree	Strongly Agree
25. The simulator panels portray the various systems in a realistic manner			7	1
26. It is easier to use actual equipment for trouble-shooting instruction rather than to use the simulator	2	5		
27. It is easy to switch the various panels on the simulator			7	1
28. When a student is working with the simulator he should be in a location where other students can not bother him		1	6	1
29. The area where a student works with the simulator should be relatively quiet		2	5	1
30. The simulator dehumanized vocational instruction	2	3	2	
31. Students should be scheduled on the simulator for periods of time ranging from one to 14 minutes	4	4		
32. Written materials should be used in conjunction with the simulator when basic troubleshooting instruction is being given		1	6	1
33. Written materials should be used in conjunction with the simulator when advanced troubleshooting instruction is being given		1	6	1
34. It is relatively easy for several instructors to coordinate the time that they will use the simulator with their respective classes	2	1	3	1
35. Students should be scheduled on the simulator for periods of time ranging from 30 to 60 minutes	1	6	1	
36. The simulator created interest among my students			4	4
37. Students did not care for the evaluation of simulators		6	1	1
38. The simulator gives students a pattern to follow when solving a particular problem		1	4	3
39. The simulator is more meaningful as a classroom aid than as a unit for individualized instruction.	1	5	1	1

		Strongly Disagree	Disagree	Agree	Strongly Agree
40.	The simulator is not very mobile..................		4	4	
41.	With the simulator, problems can be repeated simply and without much time involved.............			7	1
42.	With the simulator, a student can learn systematic diagnosis of problems.......................		1	3	4
43.	Company service on the simulator was poor.........		4	3	
44.	The simulator is good for individual instruction..			5	3
45.	A few of the simulator problems are hard to transfer to actual equipment..........................		3	5	
46.	The simulator allows a student to work at his own pace..			6	2
47.	The student thinks for himself when he is working with the simulator............................		1	3	4
48.	Component parts of the simulator are somewhat reliable.......................................		2	5	1
49.	The simulator helps students to diagnose customers' complaints.................................	1	1	4	1
50.	It is easy for the student to follow the Handbook which is used with the simulator.................			5	3
51.	It takes a great deal of time to teach each student with the trainer, but less than by other means...		2	4	2
52.	By using the simulator a teacher is allowed time to carry on other activities....................			6	2
53.	The simulator program is very close to reality...			6	2
54.	Students who did not understand the simulator instruction tended to skip over it..............		2	6	
55.	The simulator gave students more confidence in performing troubleshooting activities............			6	2
56.	The simulator helps a student to think for himself		1	5	2

		Strongly Disagree	Disagree	Agree	Strongly Agree
57.	Learning time is cut in half when using the simulator		4	3	1
58.	The simulator is easy to move	1	2	5	
59.	With the simulator, more problems can be demonstrated in a shorter period of time			6	2
60.	Only a limited number of problems can be placed into the simulator		4	4	
61.	Students need little supervision when they are on the simulator		1	6	1

APPENDIX B

EXAMPLES OF INSTRUCTIONAL CONTENT

AUTOMOBILE

ENGINE TROUBLESHOOTING

an introduction
to the

System Malfunction Analysis Reinforcement Trainer

(SMART)

Prepared by Educational Computer Corporation.
Modified for use in Pa. Dept. of Education
Project No. 10064 by The Pennsylvania State
University Department of Vocational Education.

AUTOMOBILE ENGINE TROUBLESHOOTING

Introduction

The material in this booklet will help you learn how to troubleshoot or find troubles in the automobile engine. The booklet has a number of exercises which you will complete. Each of the exercises will provide you with troubleshooting experience by using the System Malfunction Analysis Reinforcement Trainer (SMART).

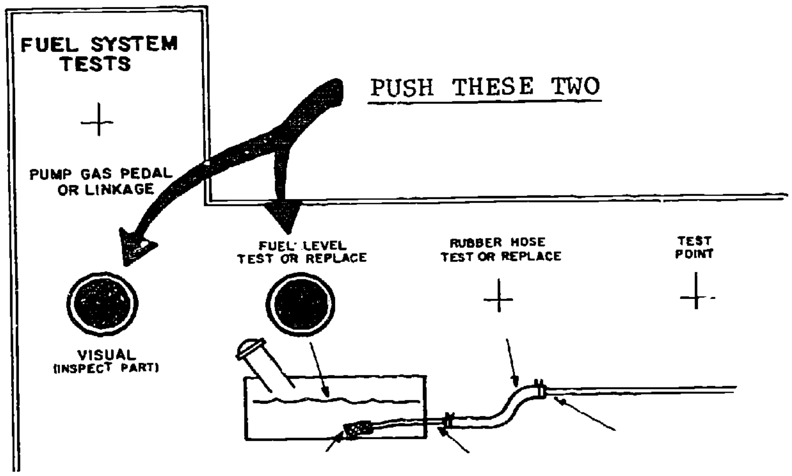
This is not an ordinary booklet; it is a self-instruction booklet. You will be given information about the automobile engine and then you will answer questions about this information. You will also be asked to perform certain checks using the SMART trainer. Be sure to read each page carefully and follow directions. Also, DO NOT WRITE IN THIS BOOKLET.

If you have any questions about the booklet or operation of the SMART trainer, call the instructor and he will help you out.

The first thing to do is place your name, school, and instructor's name on the top of the Troubleshooting Answer Sheet. This sheet will be used later on in the instruction to see how well you can troubleshoot the automobile engine. The sheet can also be used as a "bookmark" to keep track of where you are in the booklet. Remember, write on the answer sheet and not in the booklet.

After you have provided the necessary information, go on to the next page.

15. Check the gas gauge. (To do this, press the "Visual" button at the lower left and, at the same time, the "Fuel Level" test button next to it.)



16. Is there gasoline in the gas tank?

Yes ☐ No ☐ Probably ☐ Can't tell yet ☐

17. We really can't tell, but the gas gauge does register "empty."

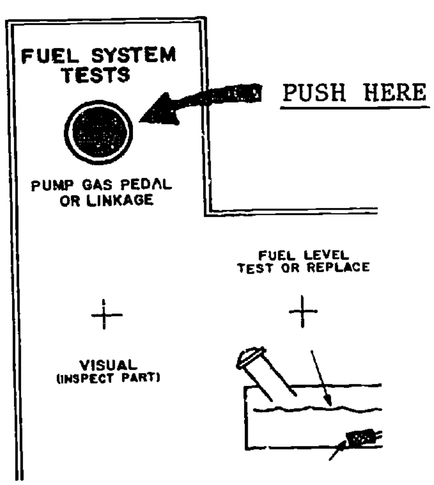
18. Next, we should check the ______________.

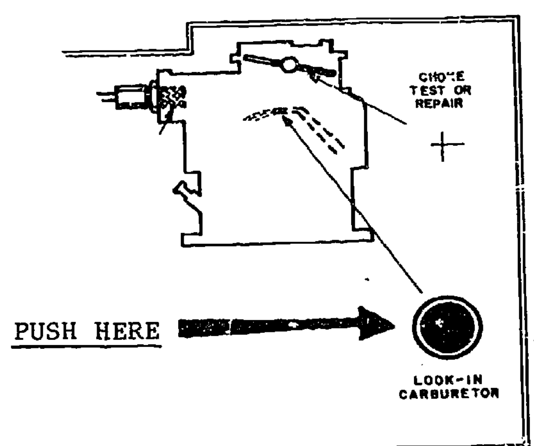
Ignition system ☐ Fuel system ☐

19. The gas gauge registered "empty," so we should next check the fuel system. We might be out of gas. If the gauge had registered gas in the tank, you would then check the ignition system next.

20. Turn off the ignition.

21. Pump the gas pedal linkage and look in the carburetor. (To do this, press the "Pump Gas Pedal or Linkage" button at the lower left of the SMART panel and, at the same time, press the "Look In Carburetor" button at the lower right of the fuel system section.)





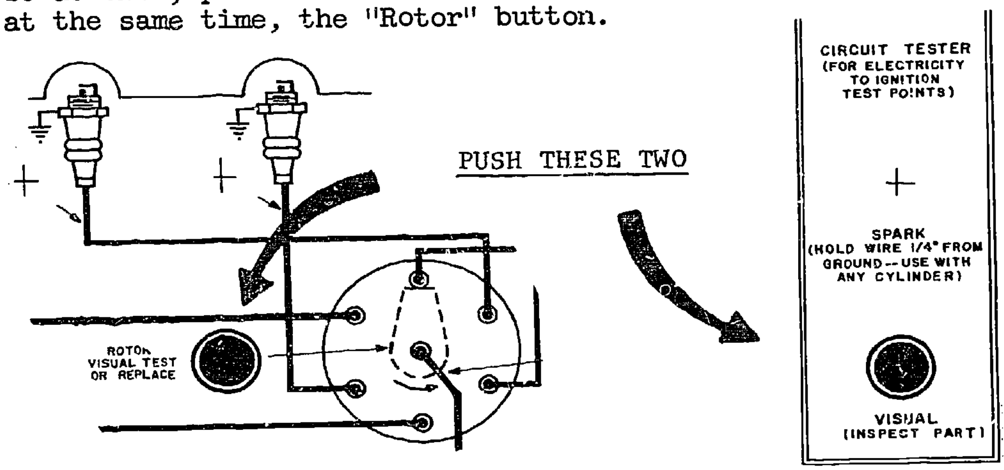
53. The distributor cap is ____________.

Good ☐ Bad ☐

54. Notice that the cap looks pretty good.

55. Let's check the rotor, looking for any defects.

56. To do this, press the "Visual" button at the right of the panel and, at the same time, the "Rotor" button.

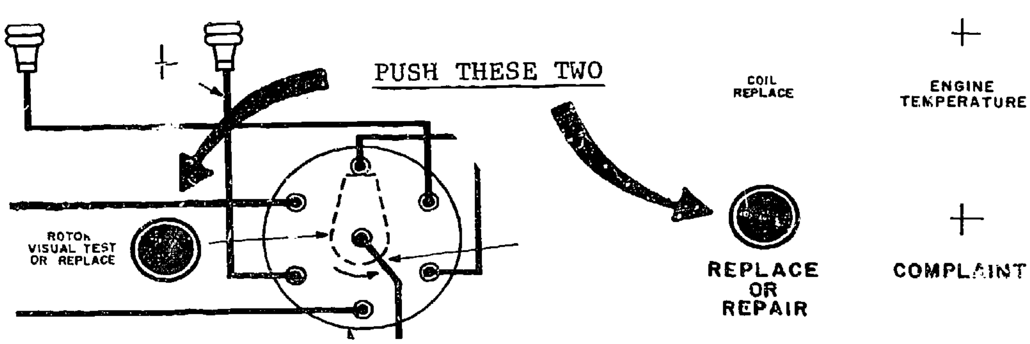


57. The rotor is ______________.

Good ☐ Broken ☐ Badly burned ☐

58. If you checked closely, you should have seen that the rotor spring was broken.

59. The rotor is bad. Replace it. (To do this, push the "Replace and Repair" button and, at the same time, the "Rotor" button.)



60. If a rotor is badly damaged, spark will not get to the spark plugs.

True ☐ False ☐

61. This is true. A mechanic must remember to check the rotor.

89. There is/are ________________ primary circuits going to the ignition coil.

One [ ] Two [ ] Three [ ]

90. There are two.

<u>First</u>: One through the ballast resistor.

<u>Second</u>: One through the starter solenoid.

91. With a circuit tester, check if battery current is getting to the coil inlet terminal again. (See Step #52 if needed.)

92. There ____________ battery current going into the coil.

Is [ ] Is not [ ]

93. Yes, there is battery current to the coil. The circuit tester did light.

94. From this we know that the primary circuit between the ____________ is good.

Ignition switch and coil [ ] Solenoid and coil [ ]

Both circuits up to the coil [ ]

95. We only know that the circuit between the ignition switch and coil is good. The reason is that, with the ignition in the "on" position, the battery current is delivered to the coil through the resistor.

96. Let's find out how to check the other primary circuit (the resistor by-pass circuit) leading up to the coil.

97. Crank the engine. Then check for battery current at the primary coil inlet terminal with a circuit tester. (See Step #52 if needed.)

98. There ______________ battery current to the coil.

Is [ ] Is not [ ]

99. Yes, there is battery current, because the circuit tester did light.

100. This tells us that the resistor by-pass circuit is okay.

Yes [ ] No [ ]

101. Yes, it does, because electricity is getting to the coil in the crank position.

102. The two primary circuits up to the coil are checked the same way except for the position of the ignition switch.

Yes [ ] No [ ]

Now let's see how good you are at finding another trouble by yourself. You will place a trouble in the SMART trainer and then find it without any help.

First reset the elapsed time clock to zero by flipping its handle. Then reset both the test and repair counters to zero by flipping their toggle switches. Now check to be sure that the clock and counters are all on zero.

When you are ready to begin, put malfunction #11 into the trainer. Then find the trouble. When you have found the trouble, record the elapsed time, number of tests, and number of repairs on your separate answer sheet.

After you have recorded your time, tests and repairs, ask the instructor to change to the Engine Starting Problems - 2 panel. Then go on to the next SMART exercise.

TROUBLESHOOTING ANSWER SHEET

1. Name: ________________ Date: ________

2. Area Vocational Technical School: ________________

3. Teacher's Name: ________________

(From page 4.15.1)

4. Malfunction number [8] was solved in [ ] minutes and [ ] seconds using [ ] tests and [ ] repairs/replaces.

(From page 9.21.1)

5. Malfunction number [11] was solved in [ ] minutes and [ ] seconds using [ ] tests and [ ] repairs/replaces.

(From page 12.11.1)

6. Malfunction number [9] was solved in [ ] minutes and [ ] seconds using [ ] tests and [ ] repairs/replaces.

Today's date is [ ].

D 1 S 2 S 3

0 4 2 5

6 7 8

9 10

11 12 13

14 15

16 17 18

19

20 21 22

23 24

25 26

27 28 29

30 31 32

33 34

35 36

37 38 39

40 41 42

43 44

45 46

47 48 49

50 51 52

53 54 55

56 57 58

59 60 61

62 63 64

65 66 67

68 69 70