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Instructional Strategies Using Low-Cost Simulation for Electronic Maintenance

by

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A variety of instructional strategies employing visual aids were developed to improve electronic maintenance training on a complex system (Improved Hawk). Large color photos of control/indicator panels, supplemented by color slides, were developed for use in the classroom. Supplementary exercises were developed for students to use while awaiting their turn on the equipment. Students receiving the experimental training demonstrated significantly greater facility in checks, adjustments, and fault isolation than did the control group.

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FINAL REPORT

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by
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Work Unit SIMELEM

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INSTRUCTIONAL STRATEGIES

USING LOW-COST SIMULATION FOR ELECTRONIC MAINTENANCE

SUMMARY AND CONCLUSIONS

MILITARY PROBLEM

The U.S. Army Air Defense School has the responsibility of training men to maintain complex electronic equipment. Due to the critical nature of systems such as the Improved Hawk, there is limited access to equipment. Therefore, there is a need to develop training alternatives which require a minimum amount of time on the actual equipment.

RESEARCH OBJECTIVE

The research project was to determine whether low-cost simulation (i.e., photos and slides) used in conjunction with carefully engineered instructional strategies could improve training in maintenance of Air Defense Systems when administered by U.S. Army Air Defense School (USAADS) instructors.

METHOD

Lesson plans and simulation materials were developed for five blocks of instruction on the Improved Hawk IHIPIR. These were used in two experimental classes and the results were compared with two control group classes.

RESULTS

The experimental classes demonstrated superior performance involving content of the five blocks on several measures:

1) Successfully completing troubleshooting problems (simulated on equipment turned off) in the time allowed, with significantly fewer errors.

2) Demonstrating checks and adjustments faster, and with fewer errors;

3) Better scores on quizzes which involved performance-oriented items.

CONCLUSIONS

The instructional strategies and simulation methods significantly improved training where real equipment was in short supply, within the practical constraints of the USAADS situation and with minimal increase in costs.

CONTENTS

CONTENTS (continued)

TABLES

FIGURES

BACKGROUND

MILITARY PROBLEM

The Army must train men to maintain complex electronic equipment, with stringently limited time for practice on the real equipment. The training problems are especially severe with newly developed and complex equipment. One example of a critical system is the Improved Hawk System. Complex electronic simulators might provide the needed practice, but their cost and development time make this approach generally infeasible and unacceptable. Another constraint for the present research is that training must be accomplished in existing facilities by existing staff without extensive special training.

RELEVANT STUDIES IN THE LITERATURE

One promising approach to the lack of time on actual equipment is the use of very simple, low-cost trainers or mock-ups having only gross visual fidelity; for example, devices having dummy instruments, photos, or even line drawings. Studies of a variety of procedural tasks have demonstrated the effectiveness of such devices (Cox, et. al., 1965; Denenberg, 1954; Dougherty, et. al., 1957; Fox, et. al., 1969; Grimsley, 1969, a, b, c; Miller, 1958; Prophet and Boyd, 1970). However, one should not presume that such simple devices would be effective for all types of training or in all training situations. As training becomes more advanced, the students become increasingly familiar with the equipment, and therefore, may no longer need visual reference to the equipment. Also, there are increasingly complex logical inferences (cognitive requirements) involved in troubleshooting, so perhaps there is relatively less need to establish visualization processes, even though visual cues continue to be involved in the task.

Swanson (1954), using highly experienced electronic maintenance technicians as subjects, found no differences among training aids with various levels of realism. These technicians could perform effectively from general verbal directions or abstract symbols, as they had been trained to do. In a follow-up experiment, Swanson, Lumsdaine, and Aukes (1956), using inexperienced airmen as subjects, found that training with a visual mock-up did lead to superior performance on a parts recognition test, as compared with those who had similar training without the visual mock-up. One would expect, therefore, that the effectiveness of visual mock-ups would depend upon the stage of training and the kind of performance tested.

In previous ARI-sponsored HumRRO research*, the instructional system for conventional Hawk training was analyzed for influences on instructor performance. Although guided by the Program of Instruction (POI), lesson plans and vault files, the instructor has considerable latitude in his instructional approach, especially if he is a Primary Instructor. The system further tends to give more prestige to the platform instructor than to the practical exercise instructor. There is also little incentive for an instructor to disseminate apparently effective instructional strategies to others. There appears, therefore, to be a definite need for preparing instructors in performance-oriented instruction.

As part of INTERFACE, an experimental Instructor Workshop in Functional Context Training was conducted. In the Workshop, it appeared that instructors could learn to use a photo mock-up with skill and ingenuity, although at first they seemed to have considerable difficulty in faithfully following a job sequence in their instruction.

RESEARCH OBJECTIVE

The research reported here was designed to answer the following question:

> Can low-cost simulation (i.e., photos and slides) improve instruction in electronic maintenance on complex systems, such as Improved Hawk (in which real equipment is scarce), when used by typical USAADS instructors following carefully engineered instructional strategies?

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*HumRRO Work Unit INTERFACE

METHOD

SUBJECTS

The subjects were 78 students enrolled in four successive classes of the Improved Hawk Firing Section Mechanic (24C20) Program of Instruction (POI). The POI covers: (1) the Launcher, and (2) the Improved High Power Illumination Radar (IHIPIR). The first two classes (75-5, N=23 and 75-6, N=16) were pooled to form the control group, and the other two classes (75-7, N=22 and 75-8, N=17) were pooled to form the experimental group.

BLOCKS OF INSTRUCTION (LESSONS)

The research investigated effects of the methods applied to the following five blocks of instruction on the Improved High Power Illumination Radar, IHIPIR (presented immediately after the Introduction):

1. Energizing and Control Circuits, 8 periods* of classroom activity.
2. Energizing and Control Circuits, 6 periods of practice on station with the equipment.
3. AC and DC Power Distribution, 4 periods of classroom activity.
4. AC and DC Power Distribution, 12 periods of practice with the equipment on station.
5. Transmitter RF Generation, Arc Detection, and Modulator Bias Circuits, 8 periods of classroom activity.

During the first four blocks of instruction the student is learning appearance and location of various components while performing the basic operations involved in energizing the equipment, following the basic conventions of their technical manuals. Only the material in the last block of instruction is considered difficult to understand, compared with typical blocks of instruction. The classroom activity is designated

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*A period is 45 minutes with a 10 minute break between periods.

"PE 3" which stands for "Practical Exercise, type 3", signifying the intention of USAADS to make it as much like a job activity as possible, rather than like the traditional lecture.

TREATMENTS

Control Group

This section describes the general approach in the conventional classes, as a basis for comparison with the experimental treatments that will be described in the next sections.

Classroom (PE 3). The classroom work for the Control Group during the three PE 3 blocks involved theory, with large amounts of circuit-tracing using schematic diagrams. Circuit-tracing typically moved left-to-right as the instructor explained how the circuit "works". Various facts were mentioned as they applied to particular points. There were few if any visual aids beyond blackboard and chalk and schematic diagrams. Prior to this, the students have had six periods with the equipment (with only a part of that time spent close enough to the radar to become familiar with it). The average student had little more experience with the radar than the majority of readers of this report. Procedures were not described during these periods; rather, the "doing" was relegated to the work on station.

On Station (PE 1). During the two PE 1 blocks the students learned to perform checks and adjustments and fault isolation. The Primary Instructor was assisted by three other instructors (each instructor had about five students working with one radar). Each instructor works with one pair of students at a time: one student reads the procedure from the manual while the other does it. The other students were generally supposed to observe the practice. Sometimes the students not performing on the radar were instructed to perform various supplementary tasks at their tables while waiting for their turn on the equipment. It appeared difficult for the instructors to devise really worthwhile activities for those not on the radar, since the students on the equipment had to be monitored closely for safety of personnel and equipment.

Experimental Group: Instructional Strategies

For the experimental classes new instructional strategies were devised. An instructional strategy is a general rule for presenting content information so that it is easier to learn and apply on the job. These rules cover sequencing of instruction and various other practices. Each instructional strategy tends to be especially appropriate for particular purposes and for particular kinds of information (e.g., in learning how to do a task, it is generally efficient to practice the steps in the task sequence).

Instructional strategies are commonly referred to as "presenting things in a logical order". Although that is true, it is hardly specific enough to be of much help in designing instruction.

Instructional strategies are often used in various combinations. All the instructional strategies in this study use visual simulation, in combination with other strategies. Therefore, the effects of the visuals were confounded with the other instructional strategies, so their independent effects can not be determined.

Visual Simulation

Classroom (PE 3). The training equipment for the experimental classes consisted of two large-scale color photos (60" x 36"), one for each end of the radar, and a series of color slides. The two ends of the radar (depicted in Figure 1) contained almost all of the relevant displays and controls (although sometimes these were located behind a panel). As a general practice, the instructors were to begin with the large color photos for orientation and then refer to the slides for details on each particular teaching point.

The large color photos were hung at the front of the room in front of the chalkboard*, and were removed when necessary to use the blackboard. Before class 75-8, in order to facilitate access to the blackboard, they were mounted** on cork panels which slide in from either side. This arrangement seemed satisfactory in all respects.

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*To avoid glare from ceiling lights, the panels were tilted out (about 6") at the top.

**Mounting by a cord facilitated removal and storage.

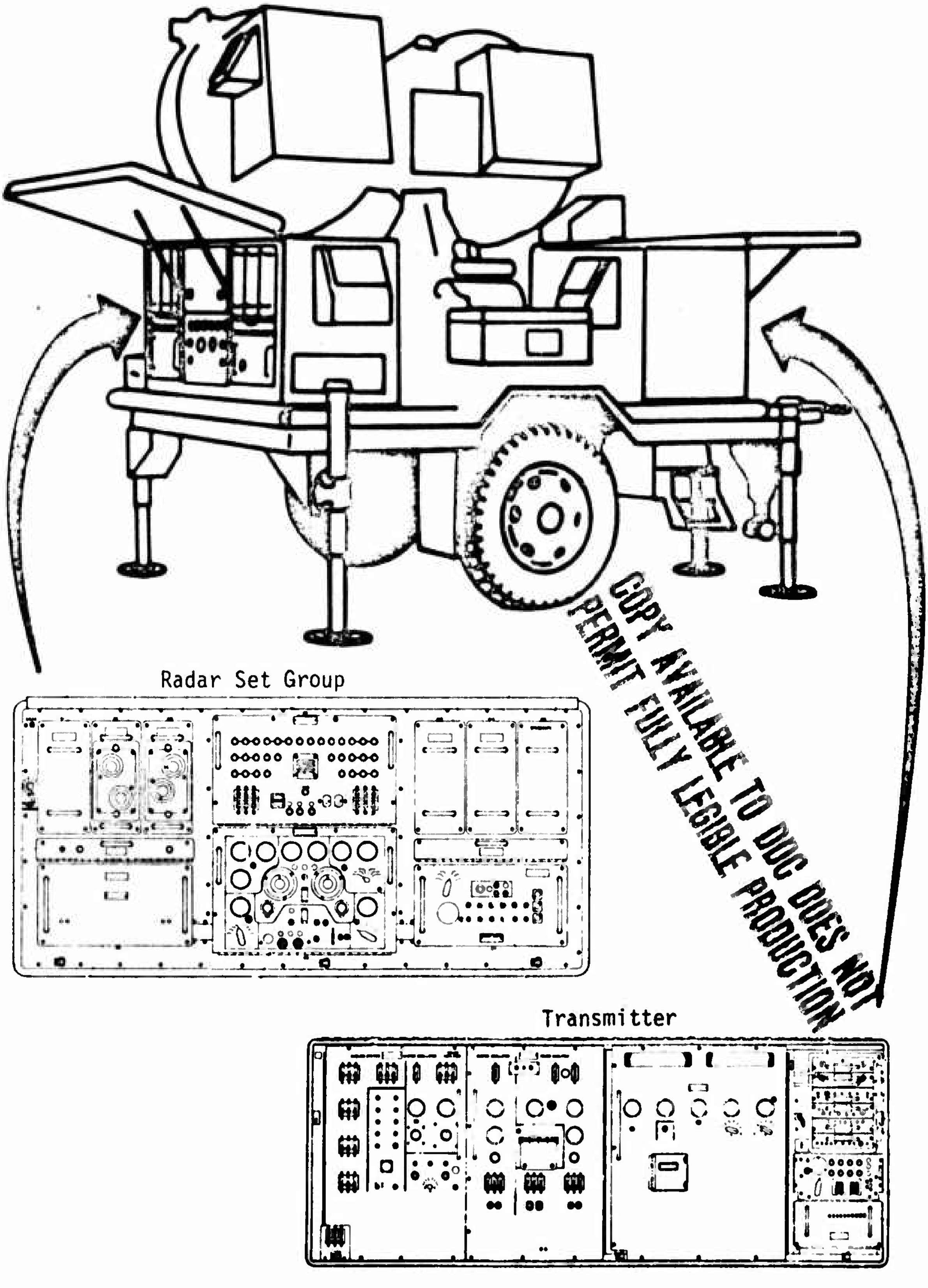

Figure 1. The two ends of the radar depicted in the color photos.

For the unit on AC and DC Power Supplies there were color photos (10" x 12") of each Power Supply. These could be hung on the large photos in the proper locations by means of small screw heads protruding from the frame.

On Station (PE 1). For each pair of students there was a set of two color photos like those used in the classroom by the instructor, but on a somewhat smaller scale (40" x 24" each). These were hung by pegboard hooks around the perimeter of each station. To represent the internal components there was a looseleaf notebook provided for each student with line drawings of the equipment located behind each of the panels, numerically coded to the panels. (Students tended to keep these notebooks available because the looseleaf covers were also handy to hold their check manuals.) Synchronized tape/slide equipment was also available.

Structuring the Lessons

The instructional strategies concern the structure inherent in the lessons. The structure is most apparent in the sequence of presentation, although it may be also a matter of emphasis and other aspects of style of presentation. In the instructional blocks studied, the most important structures to be considered are the following:

Job Situation and Job Sequence. This is a matter of presenting information as it is to be used on the job, most notably in the sequence of job performance. (However, it may be only a segment of a task to be performed.) This is often called the "functional context" method of presentation.

The job sequence in classroom presentations (along with using visual simulation) was used extensively. This was in contrast to the conventional lesson plans, which generally discussed the circuits in the sequence they appeared in the manuals.

The most common use of the "job situation" strategy was in discussing the functional diagrams. First, the checks and adjustments would be demonstrated and discussed, using the color photos and slides, showing how a trouble would lead to the Fault Isolation Procedures (FIP). Then the FIP would be demonstrated and discussed, showing how that delineates a circuit in the schematics within which the fault must lie. Then the circuit is traced and discussed, but (unlike the conventional treatment) in the context of looking for a trouble.

Identify End Points First in Schematics. This is a matter of locating the first and last functional reference points in the schematics before tracing the rest of the circuit. Thus, the goal of the tracing is identified first.

Relating Elements in Schematic Diagrams to the Equipment. In the above strategy, noting end points also served to relate the schematics to the real equipment, since the end point almost always was observable on the equipment (e.g., a meter). The slides also provided opportunity for relating points in the schematics to their visual appearance.

Grouping. This is the strategy of sorting the subject matter into natural categories. It is commonly called the "whole-to-part" method. In introducing the general categories, it is important to avoid vagueness.

In the psychological literature such grouping is called "chunking" or "advance organizers". The human mind can only think about a few items at once (this is the limit of immediate memory, or what a person is consciously aware of at any particular moment). It seems that a person can only hold about seven items (technically called "chunks" of information) in his immediate memory at one time (G. A. Miller, 1956). For instance, if a person looks up an unfamiliar telephone number (7 digits or "chunks" of information), he can probably remember it until he dials it; but if someone interrupts him by asking for some other information, that seems to "push" some of the digits out of his memory and he will probably have to look it up again.

The implication for instructional practice is that the general categories (the "whole") should be subdivided in stages, with fewer than seven subdivisions at any particular stage (generally three to five subdivisions are effective). A common mistake in applying the whole-to-part strategy is to jump from the general topic down to the detailed level, so that the learner can not relate the two levels.

A good example of the "grouping" strategy occurs in the first experimental block of instruction. Step 3 of the FIP concerns various events that might prevent the radar from going into "Standby". This generally is a matter of an interlock switch being open or faulty. This is not apparent to the novice until he gets well into the 14 substeps of Step 3, which are spread over two large (11" x 16-1/2") pages of the FIP. These interlock switches are checked out with a selector switch and indicator light at each side of the radar. The first cluster (or group) of substeps is Step 3a in which the indicator lights themselves are checked to be sure that they will give the proper indications. The second cluster covers Steps 3b through 3g in which the interlocks on the Transmitter side are checked out by a similar switch. The third cluster includes Steps 3h through 3k in which the interlocks on the Radar Set Group (RSG) side are checked out by a similar switch. The last cluster, Steps 3L through 3n, covers the remaining components that might cause trouble between the interlocks and the "Standby" indicator lights, including relays and a holding circuit. The students were directed to mark these clusters of steps in their manuals. Note that the grouping is not arbitrary, and that it corresponds precisely to visual aspects of the equipment (the switches and indicator lights).

Basic Case and Variations. It is often easier to remember several similar procedures if they are thought of simply as variations of one basic method. That way the person has many fewer items to learn. When the variations differ in complexity, the simplest is generally taught first (the so called "simple-to-complex" strategy).

This is illustrated in the above example of clustering substeps within the second and third clusters. The substeps in each of these clusters is identical in preparation and in holding the Standby button depressed, differing only in the particular position of the selector switch.

Causal Sequence. With this strategy a cause-and-effect chain of events is described in sequence. Note that this is not necessarily the same as a time sequence because the events may occur simultaneously or continuously (e.g., in a system of mechanical linkages the whole set moves together, although each link causes movement in the next one it touches, going from input to output motion).

Left-to-Right. This was not one of the experimental instructional strategies but is mentioned because it is perhaps the most commonly encountered arbitrary strategy. With this strategy the items are described in a sequence moving from left-to-right, as they occur. For instance, an instructor may describe the indicators and controls on an item of equipment "starting from the upper left-hand corner and moving across the panel". The strong "left-to-right" tendency is based upon people's reading habits. Although it is sometimes appropriate (e.g., reading schematics), it very often is not. Therefore, whenever one encounters the left-to-right sequence in instruction, one should analyze the situation to determine whether it is an appropriate strategy.

Experimental Group Instruction

Classroom (PE 3)

Energizing and Control Circuits (8 Periods). Here the predominant instructional strategy was the job sequence of checks and adjustments and Fault Isolation Procedures (FIP), illustrated with the large color photos and a series of slides. This began with a short series of checks and adjustments (Steps 1-3, Table 3-8 in TM 9-1430-533-12-1). Then each step was repeated, assuming there was a fault, which led to a corresponding step in the FIP, and using the functional schematic as specified. In Step 3 of the FIP the instructional strategy of grouping the substeps was also employed (see the lesson plan in Appendix A, Vol. II, for more details of the presentation).*

In order to further assist students in finding components of the equipment, two locator diagrams, developed by Raytheon, were handed out. Using these diagrams, the student could locate an item from knowing either the title of a block on the schematics, or the numerical code that appears by that title.

The instructor seemed to have little difficulty in adopting the methods. In his presentation he referred repeatedly to the color photos and to the slides, as required by the lesson plan. There did not appear to be any tendency to "taper off" and return to traditional methods.

AC and DC Power Distribution (4 Periods). The prominent instructional strategy here was grouping of power supplies supplemented by job sequence within each group.

The power supplies were divided into four functional groups, as described in a handout (Appendix B, Vol. II). It seemed that a major difficulty in learning to work with the various power supplies was the confusion resulting from their nine locations, and each location supplying multiple voltages. The grouping is based upon the BITE (built-in test equipment) their location, and their function in the system. The grouping corresponds rather closely with the basic block diagram of the system (Figure 24-2 in TM 9-1430-533-12-2-2).

As an overview, the instructor demonstrated where checks were to be made on each group of power supplies, located the individual power supplies within the group, and showed slides of them. Then, as each power supply group was discussed in detail, the color photos of that group were to be hung near their locations on the large photos and the photos from the previously discussed group removed so as to distinguish sharply which group was being discussed.

In both experimental classes the instructor apparently had some difficulty in hanging and removing the photos of the power supplies according to plan. Sometimes pictures of previously discussed power supplies would be left in place. Sometimes the pictures within a group were hung one-by-one rather than all at once. Therefore, the groups may have been less sharply delineated than intended in the lesson plan.

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* Volume II available from Army Research Institute.

RF Generation, Arc Detection, and Modulator Bias (8 Periods). In this presentation the instructional strategy was based upon the underlying causal sequence (as was the conventional lesson plan) supplemented by visuals showing the physical components. In this instance the Master Oscillator generates the RF energy into a waveguide, which is a rectangular metal tube. The energy passes through various components that envelop or abut the rectangular waveguide; these components monitor, rotate, modulate, or otherwise process the RF energy. These are represented schematically in Figure 24-17 of TM 9-1430-533-12-2-2. In performing FIP, the student must relate these schematics to the equipment. One of the difficult things to teach about the RF Generation was that the process could be monitored in only a few places, although this generally was rather obvious from the physical appearance (but not from the schematics). The points for monitoring show up as test jacks, crystal mounts for BITE, or other distinctive components. After the RF Generation chain was described completely, the specialized circuits for Arc Detection and Modulator Bias were described and illustrated.

On Station (PE 1)

Tape/slide presentations demonstrating checks and adjustments were developed in multiple copies. (One presentation was for Energizing and Control Circuits, one for AC and DC Power Distribution, and one for RF Generation, Arc Detection, and Modulator Bias, although the latter was not part of the experimental units of instruction.) Each tape/slide demonstration was shown once to all students in another room. Each demonstration consisted of reading the check manual with the slides demonstrating performance of the procedures.

A series of FIP problems was developed for use with the color photos and given to each pair of students. The original series of seven problems (for class 75-7) was expanded to twenty problems for class 75-8. The directions and problems are given in Appendix C (Vol. II). These problems present some critical information and approaches to FIP. However, there were difficulties in administering these problems so that effective practice conditions were assured. First, there was no way devised to insure that the students actually performed the problems conscientiously. Also, there was no way to insure that the students referred to the color photos when equipment was involved in some step. Special evaluation devices and techniques that were considered (such as an answer sheet on which erasures reveal the correctness or error of each response) seemed to entail more drawbacks than advantages. The resulting instructional procedure appeared to be rather haphazard.

INSTRUCTOR SELECTION AND PREPARATION

The instructor for the experimental classes was the instructor routinely assigned to teach class 75-7. The instructional strategies were explained to him in a briefing which emphasized visual simulation and job sequencing. The detailed methods to be followed were described in lesson plans (see Appendix A, Vol. II), prepared in the format the instructor was used to. The new methods were practiced in a dry run, with occasional comments, coaching, and encouragement by the Project Director. The Lesson Plans in Appendix A (Vol. II) reflect minor corrections and adjustments, which were requested by the instructor. A second series of dry runs was conducted similarly in preparation for class 75-8.

CRITERION TESTING

Routine Examinations

The regular examination over the first four experimental blocks of instruction was one troubleshooting problem. The student was graded not only on whether he found the fault, but also on the procedure he used. Such testing was insufficient for research purposes for several reasons. First, the testing was designed to discriminate at the lower end of the distribution, in order to determine whether a student would pass or fail, and hence, the scores tended to pile up at the upper end of the distribution, with the typical student getting a near-perfect score. Consequently, these exams did not provide much room for improvement for the average or superior student, so they have limited power for detecting differences in experimental training methods. Also, the problems were not standardized; even within a test, an examiner would change problems if he had reason to suspect that the students who had taken the exam were telling the others about it. Finally, a single problem does not provide enough information to evaluate a program.

Experimental Examinations

For the above reasons, an experimental testing program was instituted. The normal testing program was scheduled for an eight-period block of instruction during which the students were tested individually. After taking their official examination, each student in both experimental and control classes was given another examination. The examiners were regular Army enlisted instructors assisted by contractor personnel who kept time and helped maintain uniformity of procedure.

The experimental examination procedure consisted of three parts: a Practical Examination on the equipment, a Written Multiple Choice Examination, and an Attitude Questionnaire (the corresponding forms are in Appendices D, E, and F respectively, Vol. II).

Practical Examinations. During the Practical Examination the equipment was turned off and the students actually manipulated switches and pointed to dials, describing what they would expect normally. The first item was to perform all relevant checks and adjustments, followed by two Fault Isolation problems (one for Energizing Circuits, one for AC and DC Power Supplies). Directions are in Appendix D, Vol. II. For the checks and adjustments, each student was given a maximum of 10 minutes to complete Tables 3-8, 3-9, and 3-10 of TM 9-1430-533-12-1. This resulted in rank order data, depending upon how many steps they completed, or if they completed the entire procedure, how fast they completed it. The number of errors were also noted. For the Fault Isolation problems, each student was allowed five minutes for each of the two problems. The instructor would provide feedback verbally at each step. One problem concerned an interlock (in the Energizing and Control Circuits) and the other involved a defective Power Supply (from the lessons on AC and DC Power Distribution). The resulting data are whether each student successfully completed the problem in the 5 minutes allowed, and the number of errors made.

On the Transmitter RF Generation, Arc Detection and Modulator Bias Circuits, the testing was done in conjunction with another Practical Examination later in training. That experimental testing consisted of one representative check procedure and one relevant problem in troubleshooting. For the check procedure, each student was given 8 minutes to complete Step 19 of Table 3-11. This yielded rank order data, plus a tally of errors, as in the earlier check procedure. For the Fault Isolation problem, each student was allowed 7 minutes, and it was noted whether the problem was completed successfully, and the number of errors made.

Quizzes. During the same examination period that each class was given their Practical Examinations, they were also given short quizzes (Appendix E, Vol. II). The items in these quizzes were designed to involve some critical element of job performance. One quiz covered Energizing and Control Circuits. Class 75-5 took a completion form of this test, which proved difficult to score objectively; hence, they were not included in the analysis of quiz scores for Energizing and Control Circuits. The quiz on Energizing and Control Circuits consisted of identifying the nine locations of the power supplies.

Opinion Questionnaires. To supplement the test data, questionnaires were administered to all classes (Appendix F, Vol. II), in which the students rated the general effectiveness of instruction. One section, administered to the Experimental Group only, asked for absolute judgments of the effectiveness of the visual aids and FIP problems.

ANALYSIS

COMPARABILITY OF GROUPS

The comparability of the Experimental and Control Groups was first established by comparing them on the E.L. Score of the Army Classification Battery (ACB) by which they were qualified for the 24C20 POI.

DATA SPECIALLY COLLECTED

Practical Examination Scores

Checks and Adjustments. Here the data consisted of rank-ordered scores, based upon speed in completing the checks (differences tested by Mann-Whitney "U") and the number of errors in performing them (differences tested using χ^2).

Troubleshooting. There were two FIP problems administered on the first examination day, and one on the second. It was noted whether each person successfully completed each problem in the time allotted, and the number of errors. The χ^2 statistic was used to test significance of both completion and errors.

Quizzes

Differences between group means for each of the three short quizzes were tested using the "t" test.

Opinion Questionnaires

Only descriptive data were computed for the student questionnaires.

RESULTS

COMPARABILITY OF GROUPS

On the E.L. Score of the Army Classification Battery (for those scores available), the mean for classes 75-5 and 75-6 (Control Group) was 112.25 ($n = 39$), and for classes 75-7 and 75-8 (Experimental Group) was 112.77 ($n = 27$). The very small difference was well within the range that would be expected by chance alone. It is assumed, therefore, that the groups were comparable.

ROUTINELY ADMINISTERED EXAMINATIONS

The results of the first school practical examination were highly skewed, with the majority scoring above 90%. The median score (50th percentile) for classes 75-5 and 75-6, taken together was 96 out of 100, compared with 95 for the experimental classes (75-7 and 75-8). The difference was not significant.

EXPERIMENTAL PRACTICAL EXAMINATION

Checks and Adjustments

The classes were compared on rank-order data, derived from the speed with which they performed the procedures specified in Tables 3-8, 3-9, and 3-10 (TM 9-1430-533-12-1). An appropriate statistic is the Mann-Whitney "U" (Siegel, 1956, pp. 116-126) which tests whether one group ranks significantly higher than another when the two are combined in a rank-order distribution.

When the Experimental Group (classes 75-7 and 75-8) was compared with the Control Group (classes 75-5 and 75-6), the Experimental classes scored significantly better ($z = 5.89$, $p < .001$). Only four men in the Experimental Group scored below the median for the Control Group; no one in the Control Group scored above the median for the Experimental Group. This was a cumulative effect over the first four experimental blocks of instruction, and the separate effects of particular blocks could not be isolated. The Experimental Group also tended to make significantly fewer errors (Table 1, $\chi^2_2 = 11.08$, $p < .01$).

On the second Practical Examination covering RF Generation (Step 19 of Table 3-11, TM 9-1430-533-12-1) almost all of the students did finish within the time limit (8 minutes) so the data were rank-order based upon time to finish. The Experimental Group was significantly faster ($z = 2.28$, $p < .05$). This difference was much smaller than the corresponding one in the previous test on checks and adjustments, although still significant statistically. The median score for the Experimental Group was near the 70th percentile for the Control Group. The differences in number of errors (Table 1) was not significant.

Troubleshooting

During the first Practical Examination each student also performed two troubleshooting problems on the equipment with the instructor verbally supplying feedback. (See Appendix D, Vol. II, for details.)

On the first problem 34 out of 39 students in the Experimental Group completed the problem successfully while only 20 out of 39 in the Control Group (classes 75-5 and 75-6) completed it. (Results in Table 2.) This difference was significant statistically ($\chi^2_1 = 13.2$, $p < .001$).

On the second problem the Experimental Group also performed better: 26 out of 39 completed it, compared with 11 out of 39 in the Control Group ($\chi^2_1 = 10.56$, $p < .001$). They also made significantly fewer errors ($\chi^2_2 = 15.92$, $p < .001$).

On the problem in the RF Generation system (Table 3), the Experimental Group tended to finish somewhat more often ($\chi^2_1 = 5.3$, $p < .05$), although there was no significant difference in the number of errors made.

Quizzes

On the quiz covering Energizing and Control Circuits, the Experimental Group scored significantly better ($\bar{X} = 5.23$ vs. 4.22, $t = 4.372$, $p < .001$) than the Control Group (class 75-6 only, as noted previously under METHOD). Similarly, on the quiz on locations of the power supplies, the Experimental Group scored significantly better ($\bar{X} = 7.82$ vs 5.94, $t = 4.67$, $p < .001$).

On the quiz covering RF Generation, Arc Detection, and Modulation Bias, the Experimental Group also tended to score somewhat better ($\bar{X} = 9.35$ vs. 7.42, $t = 3.24$, $p < .01$).

TABLE 1. EXPERIMENTAL PRACTICAL EXAMINATION, ERRORS ON CHECKS AND ADJUSTMENTS

		0	1	2 or more
Tables 3-8, 3-9, 3-10. (χ^2_2 = 11.08, p < .01)	Experimental Group	14	9	16
	Control Group	3	7	29

		0	1	2 or more
Table 3-11, STEP 19. (χ^2_2 = 1.30, n.s.)	Experimental Group	7	15	17
	Control Group	11	13	14

TABLE 2. PERFORMANCE ON FAULT ISOLATION PROBLEMS IN FIRST EXAMINATION PERIOD

Problem 1 (Interlock)

	DID NOT COMPLETE IN TIME	COMPLETED IN TIME	ERRORS		
			0	1	2 or more
Experimental	5	34	27	10	2
Control	19	20	11	14	14

$\chi^2_1 = 13.2, p < .001$ $\chi^2_2 = 16.4, p < .001$

Problem 2 (+100 VDC Power Supply)

	DID NOT COMPLETE IN TIME	COMPLETED IN TIME	ERRORS		
			0	1	2 or more
Experimental	13	26	15	20	4
Control	28	11	6	13	20

$\chi^2_1 = 10.6, p < .001$ $\chi^2_2 = 15.9, p < .001$

TABLE 3. PERFORMANCE ON FAULT ISOLATION PROBLEMS IN SECOND EXAMINATION PERIOD

Problem 1 (Crystal Detector)

	DID NOT COMPLETE IN TIME	COMPLETED IN TIME	ERRORS		
			0	1	2 or more
Experimental	3	35	7	12	19
Control	11	28	5	5	29

$\chi^2_1 = 5.3$, $p < .05$ $\chi^2_2 = 5.3$, n.s.

Opinion Questionnaires

All classes held rather favorable attitudes toward the instruction; differences between Experimental and Control Groups were negligible (see Appendix F, Vol. II). These data are summarized in Table 4. Attitudes of the experimental classes toward the particular experimental practices were generally rather favorable. On use of media in the classroom all but one of the students rated it "somewhat helpful" or "a definite help". Similarly, on the paper troubleshooting problems, all but two students rated them "somewhat helpful", "helpful", or "very helpful". However, attitudes toward the tape/slide demonstrations of checks and adjustments were somewhat less favorable: twelve of the students rated them in the lower categories of "of little help" or "a waste of time".

TABLE 4. QUESTIONNAIRE SUMMARY

The following data are mean check ratings of how interesting and effective the instruction was, based upon a nine-point scale with 9 being most favorable. Ratings are averaged across subjects and across the four questions.

	EXPERIMENTAL	CONTROL
CLASSROOM	5.7	6.4
ON STATION	7.2	7.1

(See also Appendix F, Vol. II.)

DISCUSSION AND INTERPRETATION

The experimental instructional strategies employing visual simulation, in general, produced significantly greater ability to perform job procedures in a specified period of testing time, with significantly fewer errors, and also resulted in significantly better quiz scores. These results were achieved by a typical instructor of USAADS Primary Instructors, with preparation involving a briefing, lesson plan, and a "dry run" for practice, which is normal preparation for any new method of instruction. The experimental instructional methods also did not require extensive devices and they were practicable in the USAADS instructional situation.

The effects of the various practices are thoroughly confounded in the results. However, based upon observations of the process, it seems reasonable to attribute most of the results, tentatively, to the classroom activities. These practices affected many hours of instruction very noticeably. The paper troubleshooting and tape/slide demonstrations of checks and adjustments affected, at most, only a few minutes of instruction. Also, performance on the problems was not subject to effective monitoring practices, so there was little incentive beyond intrinsic interest in the problems, and a rather tenuous relationship to eventual test performance. Yet, the students reacted favorably to the problems, according to the opinion data, so the few minutes spent on them involves no drawbacks and may well be helpful.

There is a strong tradition in electronics training that relegates theory to the classroom and performance to the actual equipment. During the development, several instructors commented that actual performance is <u>not</u> the sort of thing that is taught in the classroom, and there was sometimes confusion concerning whether we were discussing PE 3 (classroom) or PE 1 (work with the equipment). Thus theory and practice have come to be increasingly separate (in spite of official directives to the contrary). The instructional strategies using visual simulation are based upon quite a different point of view: that theory and practice are quite compatible, that they can and should be taught together, and that visualization is actually an important tool for thinking.

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