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Application of Training Research Literature to Maintenance Performance Training

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For this report, we reviewed published data on maintenance performance deficiency at the U.S. Army Ordnance Center and School (USAOCS) and in U.S. Army Forces Command (FORSCOM) units. This review established a need for better training and job aiding of maintenance personnel. We then analyzed the literature on skill acquisition, retention, and transfer. From this literature we derived training and research implications. Finally, we generated a set of 10 guidelines for developing effective training.

We found that failure among wheel vehicle mechanics to perform to standard is a significant but predictable problem. Many valid techniques and strategies exist which could reduce this problem to a negligible level, but they are not being used or are being used ineffectively. To implement them correctly, wheel vehicle maintenance training has to shift away from a "stand-up lecture/content oriented" philosophy to one that is "workshop/task oriented."

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19. ABSTRACT (Continued)

The techniques and strategies have been condensed in the Guidelines for Improving 63W Training. These can be used to design a model program of instruction at the U.S. Army Ordnance Center & School. However, they should be useful at other Training and Doctrine Command (TRADOC) installations as well.

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Application of Training Research Literature to Maintenance Performance Training

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FOREWORD

The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI), working in cooperation with the U.S. Army Training and Doctrine Command (TRADOC) and with TRADOC's schools, conducts research for development on ways to achieve more cost-effective training for the Army. In 1987 ARI joined with TRADOC and the U.S. Army Ordnance Center and School (USAOC&S) to form a partnership at the Aberdeen Proving Ground in Maryland dedicated to identifying and solving maintenance training problems. The partnership was defined by a memorandum of understanding entitled "Establishment of a Training Technology Field Area (TTFA) at the USAOC&S" and dated 10 May 1987.

The present research report is one result of that partnership. The work was carried out by members of the Automated Instructional Systems Technical Area (formerly the Logistics Training Technologies Technical Area) of ARI's Training Research Laboratory to supply practical guidelines for designing maintenance training that will result in a high degree of skill retention and transfer.

This and other products of the TTFA were briefed to the Deputy Assistant Commandant, USAOC&S, in October 1988. It will be used to help develop model training instruction and plan additional TTFA projects at USAOC&S. Its value was recognized by MG Ball, Commandant, USAOC&S, in a letter of appreciation to the authors.

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APPLICATION OF TRAINING RESEARCH LITERATURE TO MAINTENANCE PERFORMANCE TRAINING

EXECUTIVE SUMMARY

Requirement:

Generate training development guidelines to improve skill acquisition, retention, and transfer for wheel vehicle maintenance personnel. Identify research needed to complete or validate such guidelines.

Method:

We reviewed data on maintenance performance deficiency and current training practices at the U.S. Army Ordnance Center and School (USAOC&S) and in U.S. Army Forces Command (FORSCOM) units. This review showed that we need to better train and job aid maintenance personnel. We then analyzed the literature on skill acquisition, retention, and transfer. From this literature we derived training and research implications. Finally we generated a set of 10 guidelines for effective training.

Findings:

1. Failure among wheel vehicle mechanics to perform to standard is a significant but predictable problem in the Army.

2. Many valid techniques and strategies exist, which could reduce this condition to a negligible level.

3. These techniques and strategies are not being used at APG, or are being used ineffectively.

4. To implement them correctly, wheel vehicle maintenance trained needs to shift away from a "stand-up lecture/content oriented" philosophy to one that is "workshop/task oriented."

5. The techniques and strategies are fully consistent with and support TRADOC's systems approach to training (SAT). They are validly implemented by the Harless Workshop on Front-End Analysis, Job Aiding, and Course Development.

6. The techniques and strategies have been condensed into a checklist for improving 63W training.

Use of Findings:

1. The findings can be used to design a model program of instruction at the U.S. Army Ordnance Center & School as well as at other TRADOC schools.

2. Section 4.2, "Training issues not well resolved," will be of particular interest to TTFA's since it identifies unresolved training issues.

3. We present our "Checklist for Effective Training Development" below. The checklist outlines our findings and guidance in a simple format. Use the checklist to check developed training and to guide the development of training. Use the report, and especially Chapter 5, to aid you in understanding, applying, and explaining the checklist.

Checklist for Effective Training Development

Prologue:

1. Use of the checklist will reduce net training costs and increase unit readiness by increasing skill retention and transfer to new equipment.

2. Even if a few checklist items are applied or the checklist is applied less stringently, significant improvements will result.

3. Since many of the checklist items may demand extra resources, they will have to be applied to a prioritized list of tasks. For high priority tasks, all the items can be applied "full strength." For lower priority tasks, some of the items can be implemented.

Checklist for Effective Training Development

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1. Identify problem tasks. ☐

2. Identify problem steps in task: Discriminations, Generalizations, Easily forgotten steps, "Instinctive" performance. ☐

3. Integrate B K & S with task training. ☐

4. Use a workshop training procedure. ☐

5. Use 5-P principle: ☐
   - Prime
   - Prompt
   - Perform
   - Practice isolated task
   - Practice task with related tasks.

6. Raise the standards and use remedial training to achieve them. ☐

7. Sequence the training: Overview to specific, Familiar to unfamiliar, Concrete to abstract. ☐

8. Doing part task training: ☐
   - o Break long tasks into groups of steps; ☐
   - o Use natural groupings and give them meaningful labels; ☐
   - o Teach each group as a separate training exercise; ☐
   - o Train students to recognize completion of each step; ☐
   - o Provide extra practice for difficult steps; ☐
   - o Highlight abstract materials and difficult steps; ☐
   - o Decrease help as students gain skill on a task; ☐

9. Train for retention and ability to work new equipment. ☐

10. Improve job aiding and Technical Manual training. ☐

APPLICATION OF TRAINING RESEARCH LITERATURE TO MAINTENANCE PERFORMANCE TRAINING

CONTENTS

APPLICATION OF TRAINING RESEARCH LITERATURE TO MAINTENANCE PERFORMANCE TRAINING

1.0 INTRODUCTION

1.1 Overview

This report is one of a series in the Training Technology Field Activity (TTFA) program to improve automotive maintenance training at the U.S. Army Ordnance Center & School (USAOCS). In the report we review maintenance performance problems, current training practices, and the training research literature over the last 25 years. On the basis of that literature, we recommend ways to improve introductory training of Wheel Vehicle Mechanics (63W10s). In so doing, we underscore a number of fundamental discrepancies between current training practice and well established, scientifically based principles of effective instruction.

1.2 Background

a. The Army Research Institute joined USAOCS and TRADOC's Training Technology Activity (TTA) in a TTFA at Aberdeen, Maryland. The goal of the TTFA was to identify shortfalls in maintenance performance and then build one or more model course segments to demonstrate how those shortfalls could be reduced through improved training methodology. To identify the shortfalls, TTFA staff audited the 63W10 Course at Aberdeen, and collected end-of-block test data. We then assessed performance in FORSCOM and reserve component maintenance units. These activities were designed to point to tasks not being performed satisfactorily. But, they would not tell us how to revise the training to reduce the performance deficiencies.

b. The project summarized by this report was designed to help solve that problem by deriving research-based guidelines on how to make 63W10 training more effective. Our strategy was to develop a set of general principles that are not task specific and then apply them to the deficient tasks. To better focus our efforts and economize our resources, we chose to start with an existing, candidate set of guidelines developed by Harless (1982) and to use the research to validate those guidelines and/or revise them in accordance with conclusions from the research.

c. We chose Harless (Appendix 1) because TRADOC has sponsored workshops in this methodology at 10 of its schools, and because the methodology is completely consistent with TRADOC Regulation 350-7 on the systems approach to training development. Harless provides a set of job aids which show you how to implement each of the stages of training development outlined in the regulation. His two-week workshop teaches how to use the job aids to analyze performance problems and produce job aids and course material where skill deficiency is the problem.

2.0 METHOD

2.1 Overview

a. Review of Performance Problems and Current Training Practice. We began our analysis by examining reports and data on performance deficiencies among wheel vehicle maintenance trainees and journeymen (Kern & Hayes, 1983; Macpherson et al., 1988a; Mirabella, 1988; Ramsay et al., 1988a, 1988b). We also reviewed current training practice and philosophy in the 63W10 POI at USAOCS (Ramsay et al., 1988a, 1988b). The reason for these reviews was to establish the need to produce guidelines for improved training at APG.

b. Research Literature Analysis. We designed a data analysis form with three columns. Column 1 is for conclusions derived from reviews of training research literature and literature reviews. Column 2 was designed for comments on what the literature means for instructional technology, in particular the Harless methods. Column 3 outlines additional research needed to fill gaps in knowledge about effective training methods.

c. Development of Guidelines. Here we used an approach from a companion TTFA project designed to produce rules for developing classroom visual aids (Ramsay et al. 1988b). There we wrote rules, illustrated how current practices violate the rules and then showed how to use them properly. We used the same approach to write guidelines for improving 63W10 training, i.e. from the data base of the literature analysis, we extracted a set of rules. In a separate report (Macpherson, Patterson, and Mirabella, 1988b) we will show how current practices might be improved by applying the rules.

2.2 Maintenance Performance Deficiencies and Current Training Practice

a. We reviewed and summarized results from other TTFA studies as well as previous Army research. Ramsay et al. (1988a) describe, in great detail, how the 63W10 program is conducted at APG and provide some data on end-of-annex (EOF) failure rates (i.e., per cent students failing to achieve a score of 70% on a written test). The EOA data for Phase 1 (Basic Skills & Knowledge) are failure rates for 16 classes for which data were currently available. In this report we cite average failure rates per annex. Test data for Phase 2 (MOS-Specific Training), came from 8 classes for which examination scores were available at the time of the study. We cite data for 1 written EOA test and for the written portion of the end-of-course test since these had notable failure rates. (Other tests had zero or near zero failure rates.)

b. Ramsay et al. (1988a) also summarize a study by TRADOC's Analysis Command (TRAC). TRAC measured hands-on performance for 5 tasks at 5 FORSCOM locations. The criterion for passing was stringent.

Soldiers (63Ws and 63Bs) had to pass every step with no intervention by a supervisor in order to pass the test. We cite over all results in this report.

c. A study by Macpherson et al. (1988) applied the ARI Skill Retention Model to a number of wheel vehicle maintenance tasks of special concern to SMEs at APG or actually observed in FORSCOM units as part of the TTFA's front-end analysis of maintenance performance. We identify 3 tasks subject to severe skill decay following last practice.

d. Finally, we cite representative failure rates from a study by Kern and Hayes (1983), in which hands-on performance by 236 wheel vehicle mechanics was observed.

2.3 Research Literature Analysis

a. To focus our analysis of the research literature on skill training, we emphasized applied military research, especially the work of ARI in its skill retention program conducted from about 1979 to about 1985. We were, however, led to a very large body of basic research on memory, which, while neither military nor applied, was very useful. It verified much of what was in Harless, but also pointed to some major gaps in the Harless methodology.

b. ARI's skill retention work began with empirical studies in a variety of TRADOC schools, including USAOCS. It climaxed in a highly valid and reliable method for predicting skill retention as a function of time and task characteristics. Our starting point for analyzing this work was the review by Rose et al. (1981). However, we often went to the original sources because the review was not detailed enough for our analysis, And, sometimes we disagreed with the conclusions in Rose et al. We did find their topic headings useful for organizing our own data base, e.g. Training Methods: Effects of Overtraining.

c. Additional points of departure were provided by the reviews of Farr (1986) and Schneider (1985). Farr was a particularly fruitful source of information and conclusions, but here again as with Rose et al., we found it necessary to go to the originals for the details needed for our analysis and applications. And, again, we borrowed topic headings.

d. To actually do the analysis we reviewed the materials above and then filled out the data forms described in Section 2.1.b. These completed forms constitute our raw data. For archival reasons, we've included them as Appendix 2. From them we prepared Section 3.0, Results. We reorganized the materials and conclusions therefrom under the categories of instructional design variables shown below. To arrive at the category labels , we examined those used by Rose, Farr, and Schneider, and then extracted a set of labels which seemed to cover those reviews in a frugal way:

(1) Instructional Strategy

(2) Task Characteristics

(3) Training Methods

(a) Training Evaluation and Standards

(b) Conditions of Practice

(c) Conditions Which Increase Understanding

2.4 Development of Guidelines for Revising 63W10 Training

a. Generation of list of rules. We examined in detail, the results of this study including our description of the Harless method (Appendix 1) and the revisions in the method suggested to us by the scientific literature (Appendix 2). We also examined Macpherson et al. (1988a) and Dressel (1980). We literally read through all these materials as a group of three, and extracted rules of instructional design and delivery. The preliminary result was a list of 60 items. We then condensed these into 10 major principles by combining related or subordinate items and eliminating those which were redundant. The final result is presented in Section 5.0.

b. Selection of test-bed task. We selected candidate test bed tasks from a study by Macpherson, Patterson, and Mirabella (1988a). These tasks are subject to very high rates of skill decay. They include:

(1) Diagnose stalling engine

(2) Diagnose engine which cranks, but doesn't start

(3) Replace fuel injector

We will describe the application of the guidelines to these tasks in a separate report (Macpherson, Patterson, and Mirabella, 1988b).

3.0 RESULTS

3.1 Maintenance Performance Problems and Current Training Practice

a. Performance Problems. Mirabella (1988) has extensively reviewed 25 years of Army sponsored studies of maintenance performance. We have summarized some of the more recent studies below. The studies have been consistent in showing high rates of performance failure across different testing conditions.

(1) For a sample of 16 classes, average failure rates in Phase 1 (Basic Knowledge and Skills) of the 63W10 course ranged from 5 to 31%, across seven instructional blocks (annexes), e.g. for the annex on electrical theory, the average number of people failing the end of block test was 31%. The range of failure rates across 16 classes was 9 to 76% (Ramsay et al., 1988a).

(2) For a sample of 8 classes, average failure rates in Phase 2 of the 63W10 course, were 17 and 21% for the hydraulics/ electricity (E/H) block and the end of course written exam, respectively, i.e. for the E/H block the average failure rate was 17%, with failure rates ranging from 7 to 30% across 8 classes. For the end of course written test the average failure rate was 21%, with failure rates ranging from 7 to 50%. (Ramsay et al., 1988a).

(3) In a TRADOC evaluation of 63W and 63B mechanics in FORSCOM units, failure rates across five tasks ranged from 85 to 99% (Ramsay et al. 1988a).

(4) Kern and Hayes (1983) showed widespread failures among 236 organizational wheel vehicle mechanics, on 5 different vehicles, e.g 71% of the mechanics made one or more serious, uncorrected errors involving special tools or specifications, per maintenance activity. It's noteworthy that experienced mechanics consulted the TMs for 1% of the tasks, and inexperienced mechanics used the manuals for 12% of the tasks. But even where TMs were used, failure rates were still very high. Of the mechanics who did use TMs (or other sources of information); 66% made one or more procedural errors per task compared to 79% for mechanics who did not consult a source of information to complete a task. [Incidentally, Swezey (1987) verifies that TMs don't guarantee successful performance. Novices with specially prepared job aids were able to outperform experienced electronic mechanics with only TMs].

(5) The study by Macpherson et al. (1988a) showed that skill decay for three tasks (listed in Section 2.4b) considered critical by USAOCS subject matter experts (SMEs) is predictably very severe, given the current training practices.

b. Current Training Practice. Current training practice has been documented by Ramsay et al. (1988a and 1988b) and by Macpherson et al. (1988a). In the 63W10 program, basic skills and knowledge are taught (BK&S) during Phase 1. The training approach is to lecture, usually for 50 minutes and provide group practical exercises between some of those lectures. Groups range from 2 to 5 students. An example of a PE is the assembly and disassembly of a lawn mower engine by pairs of students. Another example is an exercise on how to set up and use the STE/ICE for electrical measurements. In this case groups of five are used. In Phase 2, MOS-specific tasks are trained, again with a mixture of lecture and practical exercise, but an emphasis on the PE.

3.2 Research Literature Analysis

The detailed results of this analysis are shown in Appendix 2. The Appendix has a column of findings which are organized under training strategy, task, training methods, measurement, and motivational variables. These categories and a number of sub-categories were derived from reviews by Farr (1986), Rose et al. (1981) and Schneider (1985). A second related column comments on the relationship between the findings and the validity of training development practice and provides ideas for improving that practice, especially as it is implemented by the Harless Workshop. For reasons mentioned in Section 1.1, we are using the Harless Workshop as a representative of the systems approach to training (SAT). The findings from this effort are presented below with the citations.

a. Instructional Strategy

(1) Definition. Top-level decisions and philosophy about how to organize and orchestrate instruction is what we mean by instructional strategy. The three most top-level issues are student-centered vs. instructor-centered, content-oriented vs performance-oriented, and individualized vs cooperative learning. Most if not all the research on instructional strategies can be subsumed by these three issues.

(2) Findings.

(a) The research overwhelmingly supports methods which are student-centered and performance oriented (Walberg, 1986). But we need to qualify this conclusion. Some recent research has shown that a workshop approach which uses well-designed, live, group instruction, followed by more individualized (i.e.student-centered) techniques may be the most effective over-all strategy (Woodward, Carnine, & Gersten, 1988). Rosenshine and Stevens, (1986) suggest that, in a non-CAI classroom, 50% of the time (24 minutes in a 50 minute class) should be used for demonstration and teacher led exercises.

(b) Research also strongly supports the value of cooperative learning (Spurlin, Dansereau, Larson, & Brooks, 1984), including the cooperative use of computer-based instruction (CBI) (Shlechter,1986).

Cooperative learning is particularly effective in reducing the costs of CBI, because it can reduce the number of workstations and instructor time by at least 60%, as well as the amount of time to learn by about 30%. But within these strategies there are many, more specific issues that need to be resolved. These are addressed in the remainder of the results section.

(3) Training Development Implications. The research cited above supports the Army's System Approach to Training (SAT) as described in TRADOC Regulation 71-2, TRADOC PAM 600-11, and TRADOC PAM 351-4(T). It also supports the way SAT has been implemented by the TRADOC sponsored Harless Workshops on Front-End Analysis, Job Aiding, and Course Development.

b. Task Characteristics

(1) Definition. To develop effective training, you must first analyze the characteristics of the tasks to be trained. The results of this analysis can then be used to: (a) prioritize the tasks, given that training resources and time are always limited. (b) design the courseware, and (c) determine when refresher training may be needed. In this section we'll summarize research which now permits us to do (a) and (c). In subsequent sections we'll talk about (b), the connections between task characteristics and courseware design.

(2) Findings. In 1979, the Army Research Institute (ARI) undertook a large-scale, long-range program to study skill retention and transfer. A significant part of that dealt with the connection between task characteristics and the soldier's ability to retain his or her skill in doing the task. (Shields, Goldberg, and Dressel, 1979a). Shields et al. (1979a) developed equations to predict skill retention over 12 months from 2 variables: number of steps in the task and number of natural sub-groups of steps. Subsequently, this early work was extended and resulted in a much more accurate predictive model based on 10 task characteristics (Rose, Czarnolewski, Gragg, Austin, Ford, Doyle, and Hagman, 1985).

(3) Training implication. The foregoing research, culminating in a validated method for predicting skill retention, provides a tool to support TRADOC PAM 351-4(T). The pamphlet directs you to prioritize tasks on the basis of how quickly they will be forgotten. The Skill Retention Model lets you solve this problem in a quantitative way. This model can therefore be used by TRADOC schools to help screen tasks for inclusion in courses.

c. Training Methods

We've talked so far about selecting a general strategy or philosophy of instruction (i.e. student vs.instructor centered), and about analyzing and selecting tasks for training. The next hurdle is to define specific methods of instruction which will lead, not only to effective learning, but to retention and transfer of skills as well. The list of training method variables is large, but we can organize it into a few broad categories: use of performance evaluation data and standards; conditions of practice (e.g. amount, overlearning, variety, and spacing); conditions that increase understanding (i.e. "cognition"); and motivation of students.

(1) Training Evaluation and Standards.

(a) Definition. We usually think of training evaluation and standards as serving the accounting function of tracking or certifying student progress. But they can also be part of the instructional methodology per se and therefore used to influence skill acquisition, retention, and transfer.

(b) Findings.

Farr (1986, Page 64), for example, has shown that you can improve retention just by raising the criterion for passing tests, e.g. from the conventional 70% to 80 or 85% Based on his analysis of Slamecka et al. (1983) and Loftus (1985), Farr concluded that the rate of skill decay from any given level of retention decreases as initial skill (i.e. criterion) level increases.

TE&S can also be used to support the use of feedback, i.e. knowledge of training results or reinforcement, a well established technique of effective training. Continuous measurement of performance can provide feedback on accuracy of performance. Such feedback contributes to both acquisition and retention of skills (Schneider, 1985).

Finally TE&S can help training developers refine training methods. Shields et al. (1979b), for example, found that soldiers tend to fail the same steps within tasks. TE&S can identify such problem steps and help trainers focus resources on those steps.

On the other hand research by Schneider (1985) shows that TE&S can be misapplied. Schneider concluded from his research on skill devélopment that students should not be screened out because they perform poorly at the start of a long training program since early test results do not predict final success. TE&S can be misapplied in another way.

Go/no go measures on an entire task with many steps can give misleading information about skill decay, if only one or two steps account for the failures. This is particularly true for the situations described by Shields et al. (1979b) where the same few steps are consistently failed by many trainees. For example, in a study done by TRADOC'S Training Analysis Command (TRAC), 91 out of 98 Army mechanics failed a test in brake overhaul (Noel, 1987). But TRAC later showed that this high failure was caused by one misstep, failure to torque the bolts in replacing vehicle wheels. And even this misstep was an artifact of the test procedures.

(c) Training Implications.

Training Standards. The Army can improve skill retention of its school graduates by raising test standards from the traditional (in some schools) 70% to a higher level - perhaps 85 or 90 %. This change would increase demands on remedial training and recycling, but EIDs or other high technology training media can provide an efficient way to cope with the added demands.

The Army can further increase the efficiency of its training by using evaluation data to identify the most difficult parts of tasks, and focusing extra resources on those parts, fewer resources on less difficult parts. At the same time it needs to avoid misusing evaluation data. Go/no go measures of over-all task success need to be used cautiously. More refined measures should be considered especially to provide knowledge of results to trainees and to help training developers improve instruction. A good example of high quality, fine grained Army-relevant measurement is provided by the work of Applied Sciences Associates (1988) for the TTFA-Aberdeen. We'll develop some of these ideas in the next section on conditions of practice.

The use of evaluation data, described in the preceding paragraph fits well into the Harless Method, since it tells you to identify problem tasks and steps within tasks before you develop courseware.

(2) Conditions of Practice.

(a) Amount of Practice Leading to Initial Proficiency.

Findings. It's well established that learning increases with practice until performance reaches a ceiling. But the old adage "practice makes perfect" can actually lead to inefficient training (Shields, Goldberg, and Dressel, 1979a; Schneider, 1985). Shields et al. (1979a) found that, for many tasks, soldiers consistently failed only a few of the same steps. Schneider corroborated this finding for air traffic control. And he noted that when students repeatedly practiced whole tasks, they overtrained on frequently occurring components of the tasks, without learning less frequently or especially critical components.

Training Implication: Use part task training methods to provide extensive practice on hard or especially critical task steps. Programmed (including computer-aided) instruction can be very efficient for this purpose. The Harless method is especially well designed to provide the proper amounts of part and whole task training since it breaks tasks into small, meaningful parts, and then rolls them up into integrated exercises, finally ending in a simulation of the whole task.

(b) Variety of Training Materials.

You can increase training effectiveness by using a variety of materials or by varying the conditions of training. Doing so will improve both skill retention and transfer to new situations, but this method will especially improve transfer. It works both for initial skill acquisition, which we are talking about here, and for overtraining which we will talk about in the next section (Battig, 1979; Shea and Morgan, 1979; Farr, 1987). In particular, Schneider (1985) recommends that you should vary those aspects of tasks and conditions which may vary on the job. Keller (1983) recommends the use of variety to maintain motivation.

But too much variety introduced too quickly can have a negative side-effect. It can confuse students and increase the difficulty of initial learning. Bransford et al. (1979) recommend that you use the same or similar materials for a block of practice sessions before varying task characteristics or conditions in subsequent blocks. In addition you may need to emphasize similarities or differences in the varied materials (Engelmann and Carnine, 1982 Brooks, 1988; Perkins and Simmons, 1988).

(c) Overtraining: Practice Beyond Initial Proficiency.

Practice beyond proficiency can significantly improve skill retention (Rose et al, 1981). In fact overtraining at the school house can reduce the need for refresher training in the unit and thereby reduce the cost of such training (Schendel and Hagman, July, 1980; Rose, McLaughlin, and Felker, 1981). Moreover, the principle works for a wide variety of tasks: M60 assembly/disassembly (Schendel and Hagman, July, 1980), boresighting (Goldberg et al., 1981), and alternator/generator testing (Hagman, May 1980a).

Three repetitions of a task beyond the priming stage of training (i.e. familiarization, explanation, illustration) are optimal for maintaining skills (Hagman, May, 1980a). But to maximize transfer to new situations as well as skill retention, you need to vary the practice sessions (November, 1980b). For example, if you were teaching soldiers to test alternators, you would have the soldiers practice on three different types, rather than repeat practice on one type. In fact overtraining on the same equipment can actually interfere with ability to handle new situations. One further refinement on the principle of overtraining is necessary to maximize the effectiveness of training: Practice sessions should be spaced (i.e. separated by "rest" periods).

(d) Spacing of Practice Sessions. Long-standing basic research has shown that if students "rest" between practice sessions, they will retain what they've learned much better. Hagman (1980b) verified this principle for military training. He found that if he separated practice sessions (during overtraining) by one day and used different versions of the same equipment (i.e. varied the training materials), he could dramatically improve both skill retention and transfer to new equipment.

(e) Presentation/Explanation vs. Practice. The 50-minute stand-up lecture continues to be the dominant instructional method both in and out of the military. But the bulk of evidence indicates that students who practice individually at least part time learn and retain skills more effectively than those subjected full-time to lectures. (Rosenshine and Stevens, 1986; Swezey, Perez, and Allen, 1988; Woodward, Carnine, and Gersten, 1988). And for individual practice, a mixture of prompted and unguided practice is more effective than either alone (Hagman, January, 1980), especially if unguided practice includes some discovery learning (Wellman and Hagman, 1988). Discovery learning means that instead of "spoon-feeding" correct answers, you ask leading questions which help the student discover the right answer.

(3) Conditions Which Increase Understanding. The effects of well designed practice sessions can be much enhanced by using techniques which foster the students "understanding" of the materials to be learned and of the responses which must be made to those materials. These techniques or more properly categories of techniques include elaboration methods and the proper use of "theory".

(a) Elaboration Methods. Students recall meaningful materials more easily than those which are less meaningful. And they can use such recalled knowledge more effectively in new situations. Elaboration methods are ways that students can increase meaningfulness by associating materials and behaviors to be learned with materials and behaviors already familiar to the student. Farr (1986) mentions the following methods and supporting research:

<u>Mnemonics</u>. Mnemonics are characters, words, sentences, or pictures which help students remember facts, rules, or procedures. They take the form of similes, metaphors (verbal or graphic), acronyms, acrostics, rhymes or combinations of the foregoing. The Japanese have successfully used mnemonics, especially metaphors, to teach math, chemistry, physics, biology, spelling, and English (Higbee and Kunihira, 1985).

But a study on acrostics (to help soldiers recall procedures for operating equipment) failed to support the value of mnemonics (Dressel, 1980) for training in the US Army. (An acrostic is a sentence in which the first letter of each word denotes some other, more meaningful word). The differences here are instructive. The Japanese build their mnemonics from simple language or pictures, which are very familiar to the students. Dressel's acrostics were not simple, e.g. "Explosions Usually Terrify Individual Defenders, Although Platoons Rarely Scare."

The implication for training is that you should consider using mnemonics, but make sure they are not as difficult as the material to be learned. The contrasting Japanese and ARI experiences show that you need to make the mnemonic easy and tie it to the student's existing knowledge. This connection is the key ingredient in any elaboration technique.

Semantic Coding. The research on semantic coding, cited by Farr (1986; Page 55), reaffirms again the old wisdom that meaningful materials are recalled and recognized more easily than less meaningful materials. In the semantic coding studies (Mistler-Lachman, 1974; Craik and Tulving, 1975; Bower and Karlin, 1974) the experimenters presented words to subjects and asked them increasingly "meaningful" questions about the word, e.g. lower case vs. upper case letters, word rhymes with ____ , word does or does not fit a particular sentence. The more "meaningful" the question, the higher the recall of that word in a later memory test.

The implication for training: Identify terms that may be unfamiliar or confusing to students (e.g. volt and ampere) and spend extra time defining them. Make up some sentences using the terms, and challenge students to figure out whether the sentences make sense. Have the students correct sentences which don't. Use each term once in a correct sentence and an incorrect sentence, then repeat the exercise with different sentences.

Analogies. The use of analogies is perhaps the most direct and deliberate way to connect new learning to prior knowledge. For example, electrical voltage can be "explained" by comparing it to pressure at the bottom of a waterfall. Analogies can be very effective, especially for complicated subjects like electricity (Gentner and Gentner, 1983). But students must first understand the analogy itself and then its precise connection to the material to be learned. If they don't, the analogy will interfere with learning. If, for example, you want to use hydraulics to "explain" electricity, make sure your students first understand the relevant ideas from hydraulics. Then explain how each part of the analogy is connected to each part of the new materials.

Advanced Organizers (AOs). These are previews of more detailed instruction to follow. They include introductory outlines, learning objectives, hints on what to look for, and preliminary questions. See Gropper (1987) for good examples. AOs can provide a "big picture", a "view of the forest before the trees", a "skeleton" on which to hang the "meat" of instruction. They can improve training effectiveness if they are relevant and closely tied to the main instruction, otherwise they simply waste time and resources (Ausabel, 1961).

(b) Explanation and Theory.

Definition. We've talked so far about the importance of designing the conditions of practice and about elaborating the materials to be learned to make their meaning clear. But, is it important to go further and get "beneath the surface." Should we teach what has been loosely referred to as theory, and if so what should this instruction look like, how much should there be, and when should we provide it? The value of "theory" has been much debated and that debate has occasionally been translated into extreme positions, e.g., new math with its emphasis on theory at the expense of practice, followed by a counter-reaction against teaching mathematical theory (Howson et al, 1981; Skinner, 1989). The research cited by Farr (1986) provides interesting, compelling, and plausible answers to the questions about the role of theory.

Findings. Students recall and generalize procedures better if they are taught "theory," i.e., taught the reasons for the procedures and/or how equipment is built and operates. If students are taught to understand how equipment works, they will:

- learn operating procedures faster
- remember them longer,
- work more efficiently,
- infer missing information much faster, and,
- recover from problems more easily.

However, the trainer will get the above effects only if the theory and understanding directly support the *specific skills* which students must learn in order to do a job. "How-it-works" knowledge is useless and inefficient otherwise. In particular, the literature on functional context training says that theory must support and be integrated with practice if it is to be useful (Sticha, 1987; Montague, 1988). Other literature, including a study by Kieras and Bovair (1984), a study by Alexander et al. (1987) on general training in analogous reasoning, and an assessment of "new math" by Howson et al., (1981) support this conclusion.

What kind of theory and how much is useful? Schneider (1985) found that for air traffic control, training a conceptual understanding of the control system did not ensure proficiency on the job. Kieras and Bovair (1984) similarly found that information about "theory" of equipment operation was helpful in teaching equipment operation procedures only where the "theory" was clearly linked to specific operations. In fact full, detailed, and complete explanations about how the equipment worked interfered with learning the required task. Kieras and Bovair found that "how-it-works" knowledge can be superficial, and incomplete, and still be effective in helping students learn, remember, and transfer procedural skills.

Implications for Training. Clearly, rote learning "by the numbers" is not very efficient for retention and transfer, even with elaborations such as mnemonics and analogies. Instructors/training designers need to give explanations of "why" as well as "how", i.e. the theory behind the practice. But the theory has to be relevant to and carefully integrated with task training. Instructors can't teach "shot-gun theory", hoping that students will retain and transfer task skills better. They need to first define the skills they want to build in students and then decide what background or deeper understanding would support learning the task skills. Furthermore, instructors should start their teaching with "how" explanations and weave in or follow-up with "why" explanations.

At the Ordnance School, the practice of teaching basic knowledge and skills (BKS) first, then MOS skills illustrates the wrong way to teach theory and is both inefficient and wasteful. The practice is inefficient not only because BKS and MOS training are separated, but also because much of the BKS is irrelevant. The course textbook, TM 9-8000, for example is a text on automotive engineering that has little to do with maintenance.

The Harless method minimizes the problem of misusing theory, because it focuses on required job performance. However, it goes to an extreme here, and would be more effective if it incorporated some theory training as well as more elaborative techniques. Gropper (1987) illustrates how the performance oriented approach can incorporate theory.

d. Motivating the Student. So far we've been focusing on how to design instruction which effectively develops skills. But instruction cannot be effective, or at least efficient, if student motivation is not maintained. Can we design instruction to maximize its interest to the student, as well as to maximize its effectiveness in developing skills? Yes, at least partly because what makes instruction effective also makes it interesting. For example:

(1) Reinforcement as a Motivator. Schneidner, (1985) found that by playing an "interesting" sound when students performed correctly, he reduced failure rates in an otherwise boring, day long, air traffic control training sessions from 30 to 5%. He also found he could maintain both interest and high performance by insuring that students participate actively in the instruction, through frequent responding, - e.g. every few seconds. But, a more systematic and comprehensive attack on the problem of motivation itself has been made by Keller through the Attention, Relevance, Confidence, and Satisfactions Model (ARCS).

(2) Keller's ARCS Model. From his analysis of the research on motivation, especially research on gaming techniques, Keller (1983) identified four dimensions of motivation that could be applied to instruction: Attention, Relevance, Confidence, and Satisfaction. He then developed instructional techniques for creating high values of these dimensions in instructional material (particularly computer-based).

Keller and Kopp (1987) summarized the model in a set of training design prescriptions and applied it to an introductory lesson on how to use a microscope. Keller and Suzuki (1988) did the same thing except they detailed and illustrated the prescriptions. They then applied the model to a computer-based instructional lesson on leadership.

(3) Training Implications. Student motivation is not often considered in training development. But Keller's prescriptions show some specific ways that this can be done. He has shown, in the references cited above, that those prescriptions can be applied to CBT or other delivery approaches, even lecture. His ideas, therefore, can be applied to a range of settings in TRADOC schools.

Three of Keller's dimensions are built into the Harless method: Relevance, Confidence, and Satisfaction. You can easily incorporate the fourth, Attention. Harless provides relevance by focusing on task performance that is deficient but critical to a specific job. He builds in confidence by breaking tasks into small, meaningful units and then rolling up the units into integrated exercises. He fosters satisfaction by gradually withdrawing prompts but always providing feedback to the student. He also fosters satisfaction by having the student apply newly learned skills in job simulation exercises.

4.0 DISCUSSION

4.1 Overview of Findings

a. The findings show that many valid training techniques and strategies are available to help soldiers (1) remember skills taught at TRADOC schools and (2) transfer the skills to new situations. In the absence of these methods, serious performance deficiencies can be expected, and in fact have been documented both in the school house and in the unit (Kern & Hayes, 1983; Macpherson et al., 1988a, 1988b; Ramsay et al., 1988a). We've condensed these techniques and strategies into 10 principles which we will explain at length, along with their rationales.

b. The findings also validate TRADOC's SAT training philosophy and its implementation through the Harless Associates Workshop. The fly in the ointment is that neither the philosophy nor its specific methods are much in evidence in the 63W10 program (Ramsay et al., 1988a, 1988b).

c. For example, SAT and the research we have examined clearly indicate that basic skills and knowledge (BK&S) should be derived from and very closely linked to related tasks during training. The common approach to teaching maintenance, and the one used at APG, is to teach BK&S first, as a course in engineering, rather than maintenance and then separately, at a substantially later time, to provide shop practice in the MOS tasks.

d. This ineffective and wasteful approach is aggravated by the dominant use of stand-up lectures, in place of a workshop routine which could capitalize on the widely accepted (among professional trainers and instructional psychologists) 5-P principle: prime, prompt, perform, isolated practice, integrated practice. We will explain this in the next section.

e. We were glad to find that much of the recent applied research on skill retention and transfer supports principles that have been well and long established by basic research. In particular the value of overtraining, especially if it is distributed (spread out) over several days and on different pieces of equipment has been reliably established. This is not common practice at APG, possibly because it's time consuming. But it could be applied to a few tasks that are particularly critical and subject to severe skill decay. And, this practice is one answer to the often heard complaint that mechanics who learn on one piece of equipment, may fail the same task on another piece of equipment.

4.2 Training Issues Which Are Not Well Resolved

a. The research as well as Harless suggest that long tasks are easily forgotten, but that the skill decay can be substantially reduced if they are divided into meaningful sub-tasks which are labeled and then taught as separate exercises. Conclusive evidence to support such a practice would be very useful.

b. The value of mnemonics and analogies are well established. But how do you design them for particular audiences and topics? We need research to help us write specifications for producing and using these techniques.

c. Our review has cited some evidence that you can maximize instructional effectiveness by combining live group instruction with individualized, particularly computer aided, training. But the number of studies on when and how to combine these two instructional delivery approaches is small. We need to more extensive evidence fron applied research on how best to integrate theory and practice. Much of what we know about the issue of integration comes from small basic studies.

5.0 PRINCIPLES FOR IMPROVING SKILL ACQUISITION RETENTION AND TRANSFER

Prologue: If you use these principles you will reduce net training costs and increase unit readiness by increasing skill retention and transfer to new equipment. Even if you use a few of them or apply them less strictly, you'll see major improvements in learning and performance. Since many of the principles may demand extra resources, apply them to a prioritized list of tasks. For high priority tasks, apply all the principles "full strength." For lower priority tasks, use some of them or scale them back.

5.1 Identify and prioritize problem tasks.

a. Rationale: You can train more efficiently, if you apply our guidelines to the most critical tasks which you know are hard to learn, easily forgotten, or are not transferred well to new situations.

b. How-to: Use test and field evaluation data, instructor experience with the students, and the ARI Skill Retention Model (Ramsay et al., 1988a; Macpherson et al., 1988a).

5.2 Identify steps within tasks that are difficult or are performed incorrectly by soldiers and/or trainees.

a. Rationale: Both research and evaluation data tell us that soldiers often fail to perform tasks because they have trouble with some steps, not with the entire task. Below we've identified some special problems and what to do about them.

(1) "Red flag" steps where soldiers have to choose among alternative courses of action (i.e. discrimination) or where the same or similar actions will fit different conditions (i.e. generalization). These parts of tasks need special attention and training strategies. For example you may have to break them into smaller steps. For difficult discriminations, start with easy examples and then gradually use more difficult ones. For generalizations provide practice in a variety of situations, e.g. practice troubleshooting an alternator on three different vehicles.

(2) Safety procedures are frequently violated (Shields et al., 1979a; Kern & Hayes, 1983). One reason is that these involve discriminations about how "safe is safe." But they are listed as simple procedures, not as discriminations in the usual task analysis.

(3) "Red flag" steps where it's hard to tell whether the step was performed successfully. You need to teach what might go wrong and the signs of successful vs. unsuccessful performance. The Kern and Hayes (1983) study showed that this can be a big problem.

(4) Identify tasks that require automated (i.e. instinctive) actions, e.g. tasks performed under very severe time pressure and where the soldier has to track and recall 5 or more items of information.

5.3 Integrate basic skills and knowledge (BK&S) instruction with MOS task training.

a. Rationale: BK&S training which teaches "shotgun" theory about the construction and operation of automotive power plants is very inefficient, very wasteful, and could even interfere with transfer of training rather than improve it. Research has clearly shown that background material, i.e. explanations about how equipment works, is useful only if it's closely tied to the actual tasks which people have to perform.

b. How-to:

(1) Combine related annexes from Phases 1 (BK&S) and 2 (MOS Task Training).

(2) Derive BK&S from the task analyses. Ask yourself how much and what kind of BK&S is relevant to the task. Teach only that. Caution: This is not a prescription for rote training. Mechanics have to understand how equipment works and why tasks and task steps are performed. But you need to tie explanations and task procedures closely together.

5.4 Replace stand-up lecture with workshop format.

a. Rationale: The stand-up lecture violates a basic rule of good instruction: "Learn by doing". The traditional lecture method is at least 50 years behind the times.

b. How-to: Mix lecture with group and individual exercises. Limit lecture to 20 minutes, other activities to 30 minutes.

5.5 Use the fundamental principle of good instruction, the 5-Ps.

a. Prime: Explain and/or demonstrate.

b. Prompt: Students practice part tasks with help.

c. Perform: Students practice part tasks with reduced help.

d. Isolated Practice: Students practice the whole task without help.

e. Integrated Practice: Students practice current task with previously learned tasks.

5.6 Raise test standards and improve hands-on testing.

a. Rationale: Testing is usually thought of as a way to qualify people. But, good testing is also an effective training tool. For example, you can reduce skill decay by training soldiers to a higher level of achievement. Good testing can also provide a "thermometer" to judge the "health" of a training program. It can give you clues to where and how to improve the POI.

b. How to:

1) Raise the current testing standard from 70% to 85%. Make liberal use of remedial training to achieve this standard. Incidentally, here is a good place to use high tech methods such as the Computerized Handheld Instructional Prototype (CHIP), Electronic Instructional Delivery System (EIDS), or other forms of computer assisted instruction.

2) Improve hands-on testing by having students go through all test stations at the end of Phase 2 of the 63W10 POI. The current tests are not valid because they limit students to one station out of several. Students are so limited because of the time required to test. But a compromise technique is to test on parts of tasks.

5.7 Sequence training from overviews to specifics, from concrete to abstract, and from familiar to unfamiliar materials.

a. Rationale: An overwhelming amount of both basic and applied research tells us that people learn most effectively and can retain and transfer skills best if they can tie new learning to what they already know. Each kind of sequence mentioned above is designed to put this research finding to use.

b. How-to:

(1) Use advanced organizers to help students separate the "forest from the trees", e.g. outlines, flow charts, overviews of equipment or systems. Advanced organizers can help students understand how and why different parts of a task fit together or how different tasks fit together to accomplish some larger purpose. They can also show how equipment construction and operation, and maintenance practices mesh with one another.

(2) Then train concrete tasks on simplified everyday equipment from the student's experience (e. g. use flashlight batteries, hook-up wire,

a simple on-off switch, and miniature light bulbs to introduce electrical troubleshooting).

(3) Train on actual equipment.

(4) Train on theory required to perform the task.

(5) Train on different type of actual equipment. Have students apply theory.

(6) When training students to perform a task on several types of equipment train on the additional equipment that is most like the first, then train on dissimilar equipment.

(7) Train from students' experiences, what they know, to what they don't know. Use analogies and examples that the students already understand.

5.8 Use specialized part-task training techniques.

a. Rationale: Breaking a task into smaller pieces and teaching the pieces can be a very effective way reduce skill decay. Fortunately, the research on skill retention has provided some practical rules (and reasons) for doing this.

b. How-to:

(1) Break long tasks (more than 10 steps) into smaller groups of steps and teach each group as a separate training exercises, e.g. for a 12-step task, separate it into two groups with 6 steps each. Use natural groupings and give them meaningful labels.

(2) Train students to recognize successful completion of each step, especially where tasks don't provide any natural feedback on success or failure.

(3) Provide extra practice for difficult steps, long sub-tasks that could not be divided further, discriminations, and generalizations.

(4) Use highlighting techniques to help students focus on and understand training materials, especially for abstract materials and tasks without built-in feedback, e.g special emphasis, mnemonics, analogies, probe questions. Use the techniques correctly or don't use them at all.

(5) Special Rules for mnemonics:

(a) Use familiar words and phrases which the student can understand and recall easily with no additional training.

(b) Use short words, one or two syllables.

(c) Use mnemonics only for recalling words or short phrases. Mnemonics don't work well for recalling lists of complex procedures.

(6) Special rules for analogies

(a) Make sure the students understand the analogy, e.g., if you want to use hydraulics as an analogy for electricity, teach hydraulics first, and then check the students' understanding.

(b) Ensure that both the elements of the analog, e.g., hydraulics, and the relations among the elements are similar to those of the subject matter being taught. Student must clearly see or be shown the similarity.

(c) For your benefit as well as the students', prepare a table showing the comparable elements and relationships of the analog and the material to be learned. See the diagram of electrical analogies on page 50.

(d) Different analogies may be needed for different parts of a topic, e.g., a pump pushing water through a narrowed pipe is a good analogy for explaining the effect of series resistance on voltage in an electrical circuit, but is not effective in explaining the effects of parallel resistors. A "moving crowd" analogy works better in the latter case (horse running around a track and suddenly coming to a pair of parallel gates).

(e) Bottom line: An analogy can be very helpful, but be sure the connection between it and the material to be learned is clear to your students. If in doubt, try out 2 or 3 different analogies and check your students' understanding of the analogy.

(7) Decrease help as students gain skill on a task.

5.9 Train for both retention and ability to work on new equipment

a. Rationale: It's important for students to remember the specific task training they received, but they also have to be prepared to meet new situations, e.g., new equipment. Basic and applied research provide some ideas that seem to work dependably.

b. How-to:

(1) Train each task on a specific equipment to the point that the student can perform it once unaided.

(2) Have the student perform the same task three more times on 2 or 3 different pieces of equipment. Spread the practices over 3 to 5 days.

5.10 Improve job aiding and train students extensively on using TMs especially where multiple TMs are required to perform the task.

a. Rationale: The Army provides and mandates the use of TMs. But, soldiers use them very little or not effectively. And, even if they do use the manuals, they still get hung up on how to do specific steps outlined in the TMs (Macpherson et al., 1988a; Kern & Hayes, 1983). We think a combination of better training in how to use TMs and better job aids will make a significant dent in this problem.

b. How-to:

(1) Increase the amount and quality of training in how to use TMs, especially where multiple TMs are required.

(2) Require 63W students in Phases 1 and 2 to use manuals in all aspects of training. Give extra experience in the tasks requiring multiple manuals.

(3) Develop job aids for tasks requiring multiple manuals or very difficult searches through the TMs, e.g. checklists which pull procedures together in one place. Use ARI's Skill Retention Model to identify tasks most in need of special job aiding.

(4) Example of Pay-off. For the "engine cranks - doesn't start" problem, the 50% failure rate point could move from 4 days to 3.5 weeks with improved job aiding.

c. For tasks with 8 or more facts (e.g. tolerances, formulas, nomenclature) do the following:

(1) Prepare a small, well indexed card catalog with the most frequently used tolerances, settings, and diagnostic readings. Again, the Skill Retention Model can help identify what set of facts should go in the catalog.

(2) Have students prepare their own lists of facts on cards, protected with plastic. Have trainees practice reviewing the lists. Teach the facts in groups of 3 or 4. Do this before they practice the whole task, and then after they finish. For facts used in other tasks, prepare a list of those tasks so that the trainee can see how the facts generalize. Show how the same fact (e.g tolerance, spec, formula) applies to other tasks. Cross reference the facts by page number to the TM or TMs.

6.0 CONCLUSIONS

6.1 Failure among wheel vehicle mechanics to perform to standard is a significant but predictable problem in the Army.

6.2 Many valid techniques and strategies exist which could reduce this condition to a negligible level.

6.3 These techniques and strategies are not being used, or are being used ineffectively

6.4 To implement them correctly, wheel vehicle maintenance training needs to shift away from a "stand-up lecture/content oriented" philosophy to one that is "workshop/task oriented".

6.5 The techniques and strategies are fully consistent with and support TRADOC's systems approach to training (SAT). They are validly implemented by the Harless Workshop on Front-End Analysis, Job Aiding, and Course Development.

6.6 The techniques and strategies have been condensed in a set of guidelines for improving 63W10 training".

7.0 REFERENCES

Applied Science Associates. Data Collection Plan: Improvement of 63W Wheel Vehicle Repairer Job Performance. Washington, D.C.: Applied Science Associates, 1988.

Alexander, Patricia A, White, Stephen C., Haensly, Patricia A., & Crimmins-Jeanes. Training in Analogical Reasoning. American Educational Research Journal, 1987, 24(3), 387-404.

Ausabel, David P. The Use of Advance Organizers in the Learning and Retention of Meaningful Verbal Material. Journal of Educational Psychology, 1960, 31(3), 267-272.

Bahrick, H. P. Maintenance of Knowledge: Questions About Memory We Forgot to Ask. Journal of Experimental Psychology: General. 1979, 108, 296-308.

Battig, William F. The Flexibility of Human Memory. In L.S. Cermark and F.I.M. Craik (Eds)., Levels of Processing in Human Memory. Hillsdale, N.J.: Erlbaum, 1979.

Bower, G.H. & Karlin, M.B. Depth of processing of Faces and Recognition Memory. Journal of Experimental Psychology, 103, 751-757, 1974.

Bransford, J.D., Franks, J.J., Morris, C.D., & Stein, B.S. Some General Constraints on Learning and Memory Research. In Levels of Processing in Human Memory, L.S. Cermak & F.I.M. Craik, (Eds.), New York: John Wiley and Sons, 1979.

Brooks, Judith E. Personal communication, August, 1988.

Brophy, Jere, and Good, Thomas L. Teacher Behavior and Student Achievement. In M.C. Wittrock (Ed.). Handbook of Research on Teaching (3rd ed.), New York City, N.Y.: Macmillan, 1986.

Craik, F.I.M.& Tulving, E. Depth of Processing and the Retention or Words in Episodic Memory. Journal of Experimental Psychology: General, 104, 268-294, 1975.

Doyle, Walter. Classroom Organization and Management. In Handbook of Research on Teaching (Merlin C. Wittrock, Ed., 3rd Ed.). New York: MacMillan, 1986.

Dressel, D.J. Mnemonically Enhanced Training. ARI Working Paper, February, 1980. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Engelmann, Siegfried, and Carnine, Douglas. Theory of Instruction: Principles and Applications. Irvington Inc.: New York, 1982.

Farr, Marshall J. "The Long-Term Retention of Knowledge and Skills: A Cognitive and Instructional Perspective," IDA Memorandum Report M-205, September, 1986, Alexandria, VA.: Institute for Defense Analysis.

Gagne, Ellen D., Bell, Michael S., Yarbrough, Donald B., and Weidman, Craig. Does Familiarity Have an Effect on Recall Independent of Its Effect on Original Learning. Journal of Educational Research, 1985, 79, 41-45.

Gentner, Dedra and Gentner, Donald R. Flowing Waters or Teeming Crowds: Mental Models of Electricity. In Gentner and Stevesn (Eds.), Mental Models. Hillsdale, NJ: Lawrence Erlbaum Associates. 1983.

Goldberg, Steven L., Drillings, Michael, and Dressel, J.D. Mastery Training: Effect on Skill Retention. ARI Technical Report 513, March, 1981. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. AD A120 762

Gropper, A Lesson Based on a Behavioral Approach to Instructional Design. In Instructional Theories in Action, (C. M. Reigeluth, Ed). Lawrence Erlbaum Associates: Hillsdale, N.J., 1987.

Hagman, Joseph D. Effects of Presentation- and Test-trial Training on Motor Acquisition and Retention. ARI Technical Report 431, January, 1980. Alexandria, VA.: U.S. Army Research Institute for the Behavioral and Social Sciences. AD A086 406

Hagman, Joseph D. Effects of Training Task Repetitions on Retention and Transfer of Maintenance Skills. ARI Research Report 1271, May, 1980a. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. AD A101 859

Hagman, Joseph D. Effects of Training Schedule and Equipment Variety on Retention and Transfer of Maintenance Skills. ARI Research Report, November, 1980b. U.S. Army Research Institute for the Behavioral and Social Sciences. AD A120 167

Harless, J.H. Workshop in Front-end Analysis, Job Aiding, and Course Development. Newman, GA.: Harless Performance Guild, Inc., 1982.

Higbee Kenneth, L. and Kunihira, Shirou. Cross-Cultural Applications of Yodai Mnemonics in Education. Educational Psychology, 1985, 20, 57-64.

Howson, G., Keitel, C., & Kilpatrick, J. Curriculum Development in Mathematics. Cambridge, England: Cambridge University Press, 1981.

Keller, John M. Motivational Design of Instruction. In C.M. Reigeluth (Ed.), Instructional Design Theories and Models: An Overview of Their Current Status. Lawrence Erlbaum Associates: Hillsdale, N.J., 1983

Keller, John M. & Kopp, Thomas, W. An Application of the ARCS Model of Motivational Design. In C.M. Reigeluth (Ed.). Instructional Theories in Action. Lawrence Erlbaum Associates: Hillsdale, N.J., 1987.

Keller, John M. & Suzuki, Katsuaki. Use of the ARCS Motivation Model In Courseware Design. In D.H. Jonassen (Ed.). Instructional Designs for Microcomputer Courseware. Lawrence Erlbauam Associates: Hillsdale, N.J., 1988.

Kern, Richard P., and Hayes, John F. Research Findings to Aid Supervisors and Trainers in Improving Maintenance Performance. ARI Research Product 83-14, November, 1983. Alexandria, VA.: US Army Research Institute for the Behavioral and Social Sciences. AD A144 655

Kern, Richard P., Sticht, Thomas G., Welty, Diana, and Hauke, Robert M. Guidebook for the Development of Army Training Literature. Special Publication, November, 1975. Alexandria VA.: Human Resources Research Organization.

Kieras, David E., & Bovair, Susan. The Role of a Mental Model in Learning to Operate a Device. Cognitive Science, 8, 255-273, 1984.

Loftus, Geoffrey R. Evaluating Forgetting Curves. Journal of Experimental Psychology (Learning, Memory, and Cognition), 1985, 11(2), 397-406.

Macpherson, Douglas H., Patterson, Chavis, and Mirabella, Angelo. Application of ARI Skill Retention Model to Wheel Vehicle Mechanic Tasks. ARI Technical Report [In preparation], May, 1988a. Alexandria, VA.: US Army Research Institute for the Behavioral and Social Sciences.

Macpherson, Douglas H., Patterson, Chavis, and Mirabella, Angelo. Application of Guidelines for Improving Skill Acquisition, Retention, and Transfer to Wheel Vehicle Tasks. ARI Technical Report [In preparation] May, 1988b. Alexandria, VA.: US Army Research Institute for the Behavioral and Social Sciences.

Mirabella, Angelo. Contributions of the Army Research Institute to the Training Technology Field Activity (TTFA) - Aberdeen. ARI Research Report [In preparation], May, 1988. Alexandria, VA.: US Army Research Institute for the Behavioral and Social Sciences.

Mistler-Lachman, J. Depth of Comprehension and Sentence Memory. Journal of Verbal Learning and Verbal Behavior, 1974, 13, 98-106.

Montague, William E. Promoting Cognitive Processing and Learning by Designing the Learning Environment. In Instructional Designs for Microcomputer Courseware, (D.H. Jonassen, Ed.). Lawrence Erlbaum Associates: Hillsdale, N.J., 1988.

Noel, Sylvia. Commercial Utility Cargo Vehicle Maintenance Training

Effectiveness Analysis. Training Analysis Command (TRAC) Report ATOR-TH8/SACH0006/5, 5 Jan 1987.

Perkins, D.N. & Simmons, Rebecca. Patterns of Misunderstanding: An Integrative Model for Science, Math, and Programming. Review of Educational Research, 58, 303-326, 1988.

Ramsay, Douglas, Kessler, John, J., Mirabella, Angelo, and Thoreson, R. A. Preliminary Review of the 63W10 Course at Aberdeen Proving Ground. ARI Research Report [In preparation], May, 1988a. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Ramsay, Douglas, and Mirabella, Angelo. Handbook for Producing Classroom Vugraphs. ARI Research Product [In preparation], May 1988b. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Rose, Andrew M., McLaughlin, D. H., Felker, D. B. Retention of Soldiering Skills: Review of Recent ARI Research. AIR Report, March, 1981. Washington, D.C.: American Institutes for Research.

Rose, Andrew M., Czarnolewski, Mark Y., Gragg, Frances E., Austin, Stuart H., Ford, Patrick, Doyle, Jack, Hagman, Joseph D. Acquisition and Retention of Soldiering Skills. ARI Technical Report 671, February, 1985. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. AD A166 336

Rosenshine, Barak & Stevens, Robert. Teaching Functions. In Handbook of Research on Teaching (Merlin C. Wittrock, Ed., 3rd Ed.). New York: MacMillan, 1986.

Schendel, Joel D. & Hagman, Joseph, D. On Sustaining Procedural Skills Over Prolonged Retention Intervals. ARI Research Report 1298, July, 1980. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. AD A120 758

Shlechter, Theodore M. Grouped Versus Individualized Computer-Based Instruction (CBI) Training for Military Communications. ARI Research Report 1438, April, 1986. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. AD A182 171

Schneider, Walter. Training High-Performance Skills: Fallacies and Guidelines. Human Factors, 1985, 27(3), 285-300.

Shields, J. L., Goldberg, S.L.., & Dressel, J.D. Retention of Basic Soldiering Skills. Research Report 1225, 1979a. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. AD A675 412

Shields, J. L., Joyce, R. P., and VanWert, J. R. Chaparral Skill Retention. ARI Research Report 1205, March, 1979b. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. AD A069 945

Shea, J.B., & Morgan, R.L. Contextual Interference Effects on the Acquisition, Retention and Transfer of a Motor Skill. Journal of Experimental Psychology: Human Learning and Memory, 5, 179-187, 1979.

Skinner, B.F. Teaching Machines. Science, 24 March 1989, 1534.

Slamecka, J.J., & McElree, B. Normal Forgetting of Verbal Lists as a Function of their Degree of Learning. Journal Of Experimental Psychology: Learning, Memory and Cognition, 9, 384-397, 1983.

Spurlin, Joni E., Dansereau, Donald F., Larson, Celia O., and Brooks, Larry W. Cooperative Learning Strategies in Processing Descriptive Text: Effects of Role and Activity Level of the Learner. Cognition and Instruction, 1984, 1(4), 451-463.

Sticha, Thomas G. Functional Context Education Workshop Resource Notebook. San Diego, CA.: Applied Behavioral & Cognitive Sciences, Inc., 1987.

Swezey, Robert W., Perez, Ray S., Allen, John A. Effects of Instructional Delivery System and Training Parameter Manipulations on Electromechanical Maintenance Performance. Human Factors, 1988, 30(6), 751-762.

Swezey, Robert W. Design of Job Aids and Procedure Writing. In Handbook of Human Factors, (Ed. Gavriel Salvendy). Wiley & Sons: New York, 1987.

Tyler, S.W., Hertel, P.T., McCallum, M.C., & Ellis, H.C. Cognitive Effort and Memory. Journal of Experimental Psychology: Human Learning and Memory, 5, 607-617, 1979.

Walberg, Herbert J. Synthesis of Research on Teaching. In Handbook of Research on Teaching (Merlin C. Wittrock, Ed., 3rd Ed.). New York: MacMillan, 1986.

Wellman, Rosalie, and Hagman, Joseph D. Training Procedures for Enhancing Learning, Retention, and Transfer. ARI Technical Report [In preparation], July 1988. Alexandria, VA: U.S. Army Research Institute for the Behavioral Sciences.

Woodward, John, Carnine, Douglas, and Gersten, Russell. Teaching Problem Solving Through Computer Simulations. American Educational Research Journal, 1988, 25(1) 72-86.

8.0 APPENDIX 1: SUMMARY OF THE HARLESS METHOD FOR DEVELOPING TRAINING

8.1 Front-End Analysis (FEA):

a. Identify each specific task which is not being performed to standard on the job. Then decide whether the performance failure(s) results from lack of skill. If so the task is a candidate for new or improved training.

b. Flow chart the task as a sequence of cues and actions (stimuli and responses). Show where these cue-action pairs form chains of behavior, discriminations (i.e., decisions), or generalizations (i.e., common action for different situations). It's critical in the Harless method to identify these three types of behavior, because Harless provides rules for special training strategies with each type.

c. Note also that Harless is performance not content oriented. Harless agrees with the ARI guidebook on training literature (Kern et al., 1975) that you should teach what to do and how to do things.

8.2 Training Design.

a. Break the task into subtasks, using rules provided by Harless, and then organize the subtasks into a series of training exercises which Harless calls the 5-P strategy: Priming, prompting, practice, isolated practice, integrated practice.

b. Priming means that you explain or demonstrate a subtask. Prompting means that you provide self-paced experiences with the subtask but with lots of hints about how to perform correctly. Practice is more of the same, but with less prompting, and maybe with several subtasks combined. Isolated practice means that you give the student experience on the whole task, under the most realistic conditions possible. Integrated practice means that you combine the whole task with other, related, tasks.

c. The 5-P strategy, in other words, is just a well organized way to move the student from part- to whole-task training, with gradual increases in fidelity. The idea certainly is not new. But Harless shows you exactly how to put it into practice, with rules, examples and exercises. In other words, he uses the 5-P strategy to teach the 5-P strategy.

d. When he does so, he uses a workshop format, i.e., a live instructor does the priming and then turns the students loose on workbook exercises. But, other training media or combinations of media can be used, just as easily, e.g., computer-aided instruction alone, or in combination with an instructor.

9.0 APPENDIX 2

ANALYSIS OF TRAINING RESEARCH LITERATURE

A. Variable Class: Training Strategy (Student vs. Instructor Centered)

Findings:	Harless Connection:	R + D Issue(s):
1. For the years 1969 to 1982, Walberg (1986) synthesized reviews of research on teaching. For each review, he indicated the number of studies reviewed, correlations or effect sizes for different variables and circumstances under which those variables had an influence. Training methods which support individualized, or other student centered approaches were shown consistently to be more effective than traditional classroom lecture techniques.	1. Cumulative research over many years argues against the continued Army practice of traditional, stand-up, content oriented lectures. It supports the validity of Army training doctrine which prescribes active participation of trainees in performance oriented programs of instruction. The research also supports the validity of the TRADOC sponsored Harless Workshop on Front-end Analysis, Job Aiding and Courseware Development.	1-3. Schlecter's study was limited by small sample sizes. While his results are very intriguing, they need to be replicated at other TRADOC schools, using larger samples of trainees. If we combine Schlecter's methods with those of Spurlin et al, we can answer questions about student roles and cooperative learning in a CAI environment. If we add to all this the methodology of Woodward et al, we can additionally answer questions about the role of the instructor, as well as the trainee in CAI environments. These are questions the Army needs to answer before it proceeds much further with large scale issue of EIDS hardware or development of EIDS software.
2. A number of studies suggest that individualized instruction can be over emphasized. Live instruction in a group setting can combine with individualized learning to produce better results than either approach alone (Doyle, 1986; Rosenshine & Stevens; Woodward, Carnine, & Gersten, 1988;)	2. With the advent of the Army's Electronic Information Delivery System (EIDS), individualized instruction may become the wave of the future. But research suggests that if the value and role of live, group oriented instruction is not carefully thought through along with a variety of other instructional design issues, EIDs could become a very costly "white elephant".	
3. Cooperative learning has been shown to be an effective alternative to individualized instruction, especially if the roles of the trainees working together are carefully specified using the ideas of peer instruction (Spurlin, Dansereau, Larson, & Brooks, 1984). Cooperative learning also works in CAI classrooms. Schlecter (1986) showed that cooperative learning could reduce the number of computer workstations by 60% and the time to complete lessons by 30%.	3. Cooperative approaches to CAI can provide significant ways to cope with cut-backs in Army budgets and training personnel, particularly because such approaches reduce training time and demands on instructors.	

Cooperative learning also reduced individual differences in time to complete lessons as well as demands on instructor time.

B. Variable Class: Task Characteristics (Front-End Analysis) (Rose, McLaughlin & Felker, 1981)

1. This review was the foundation of a model for predicting skill retention. 2. Authors recommend that skill retention predictions be used as a basis for selecting those tasks which will receive the special training treatments recommended by retention research.	1 and 2. Might add a rule to Harless FEA procedures which states that the Retention Model should be used to screen tasks for special training strategies. Harless doesn't explicitly deal with the problem of prioritizing tasks for training because his FEA is oriented towards finding and fixing a limited number of problem tasks. Hence training resource, for him, is not an issue. But it is for TRADOC.	1. Would the Retention Model lead to the same conclusions about problem tasks as an empirical field study? i.e. if we applied the Retention model would we identify analytically the same problems that ASA identifies empirically?
3. Authors point out that there are multiple ways to deal with the "forgetting" problem including job redesign, job aiding, and selection/classification, as well as use of special training strategies.	3a. Rose et al. reinforce the Harless perspective that you should be open to solutions other than training. Harless, however, goes a significant step further by giving rules for deciding when to use each class of solution. 3b. Rules in Harless are somewhat rigid. e.g. they have you select either job aiding or training. Perhaps we need to enrich them so that the trainer can adopt an optimal combination of solutions based on a number of factors including the skill decay projections. e.g. if the task is performed infrequently and subject to severe skill decay, but is critical and time pressured, rely heavily on special training techniques to reduce decay to acceptable levels. If the task is not time pressured, rely heavily on job aids. If skill decays on only one or two steps out of a larger number e.g. 10, consider focusing job aiding or special training on those steps.	

C. Variable Class: Task Characteristics (number of steps, number of sub-tasks, and sequence cues) (Shields, Goldberg, and Dressel, 1979. See also McClusky et al., 1978)

1. Skill decay = f(number of steps) = f(number of sub-tasks in the task)	1. and 2. Harless implicitly recognizes the problem of step-size and sub-task structure identified by ARI research and provides a solution very indirectly suggested by the research: break down long chains of S-R pairs (operants) into smaller chains and teach each sub chain as a separate exercise after demonstrating/explaining the overall task. Look for natural, logical sub-groups of operants.	1. and 2. Does the Harless rule, in fact work. If you took the tasks (from Shields et al) and taught them in chunks would the slopes of their retention curves (i.e. rate of forgetting) decrease? What effect would "Harless" have on transfer to conditions other than those used in training?
2. Regression curves developed from these and one other variable, with number of steps contributing most variance.		
3. Correlation of number of steps and regression slopes appears high but not perfect. Fig. 1, Page 3 shows some reversals. e.g. a task with 9 steps showed more performance decay than one with 15 steps.	3. Task analysis in Shields et al. is considerably less precise than what is taught by Harless: not as fine grained and not broken into chains, discriminations, generalizations, and combinations thereof.	3. If the tasks used by Shields et al. were reanalyzed into chains, discriminations, and generalizations would the correlation between the number of steps and performance improve?

D. Variable Class: Performance Evaluation (collecting and using performance data)

1. Regression slopes in paragraph C.3 were substantially higher when per cent steps passed was used as the criterion (performance looked much better when measured by per-cent steps passed. Furthermore soldiers tended to fail consistantly on the same steps. (Shields, Goldberg, and Dressel, 1979.)	1. Supports the importance of doing an analysis and evaluation down to the operant level as suggested by Harless. The ARI research indicates that performance problems can be traced to the operant level (as opposed to simply analyzing over-all go-no scores.) Studies which report only go-no go scores are not very useful for training development.	
2. Don't just give the trainee an overall score. Systematically determine and tell the student which sub-tasks and steps he is having trouble with. (Schneider, W., 1985)	2. The Harless method for developing training identifies the sub-tasks and steps that may be failure prone, thus a major portion of the trainer's task is completed.	2. Develop guidance to assist trainers and course authors in preparing tests which provide adequate diagnostic information in the form of sub-test scores on specific sub-tasks and steps.

3. Don't flunk out students who perform poorly at the start of long training programs. Initial performance is not a good predictor of final success in these circumstances. (Schneider, W., 1985)	3. The Harless approach to task analysis and his 5-P method are designed to reduce attrition to the bare minimum. Schneider's finding actually justifies Army school reliance on remediation rather than flunking trainees.	

E. Variable Class: Performance Evaluation (Effects of Changing Training Standards)

1. Its a well established fact that the shape of the skill decay curve remains constant as the criterion level is reduced from 100% So from one perspective, one can say that the rate of skill decay is independent of criterion level (i.e. level of skill acquisition). [Slamecka & McElree, 1983; Cited in Farr Page 64]. 2. Another perspective is provided by Loftus (1985), cited in Farr, Page 64. Loftus argues that rate of skill decay is influenced by criterion level, e.g. rate is less at 100% than at 70%. To arrive at this conclusion Loftus took horizontal slices through the decay curves. The preceding conclusion follows from taking vertical slices through the decay curves. (Farr, 1986)	1. and 2. Harless does not deal with criterion level. A rule about manipulating criterion level could very well be added. e.g. build in some rule about re-cycling students who don't achieve a high score, say 90% on diagnostic tests following priming, prompting, and/or practice. Re: USOCS specifically, the research suggests that its criterion level of 70% might be a significant cause of the performance deficiencies in FORSCOM units. Suggestion might be to raise the level to 80% or 90%.	1. & 2. The decay function is so well established that further research here does not seem warranted, especially in view of how expensive and difficult it is to collect the necessary longitudinal data.

F. Variable Class: Training Methods (Amount of Practice)

1. Skill decay = f(position of task in the POI. i.e. the later you train a task, the more likely it will be forgotten). This assumes that you will keep coming back to a task after you have trained it - apparently the practice at the sites where Shield's did the study. If this assumption holds then tasks trained early will be practiced more. (Shields, Goldberg, and Dressel, 1979.)	1a. Harless gives a rule which implements this finding. His rule: teach the most critical tasks or portions of tasks early in a training module or POI. Shield's et al. validates the Harless rule. 1b. This finding also indirectly supports Harless use of the integrated practice exercise, i.e. the IP exercise allows you to refresh on tasks or task segments taught earlier in the POI.	

2. Number of task repetitions leading to proficiency did not contribute significantly to predictions of skill retention [e.g even though soldier A takes 10 trails and soldier B 20 trials to reach proficiency on the same task, both will remember the task equally well at a later date. (Shields, Goldberg, and Dressel, 1979.)		
3. "Practice makes perfect" is inefficient for whole task training because you overtrain on the easy and/or frequently occurring portions of the task and provide inadequate training on the less frequent portions. Practice makes perfect is only true for S-R strings without decision components. (Schneider, W., 1985)	3. Harless emphasizes breaking training down into small S-R strings, training them, then integrating their performance with the other portions of the task. Thus the Harless training procedure solves this problem.	
4. Similarly, don't emphasize high fidelity training of the whole task. Train the component skills in simplified form, then train the more complex levels of the skill. This avoids wasting time on practicing skills that have been well learned because they occur frequently and are easily learned. (Schneider, W., 1985)	4. Schneider's research supports Harless's 5-P principle and the integration of B K & S into MOS-task training. Harless emphasizes breaking the total task into its component skills and training them.	
5. Design training to allow many trials on each critical skill in a short period of time. (Schneider, W., 1985)	5. Harless provides excellent procedures for achieving this. However, he does not provide rules for estimating how much practice is required.	5. Determine how much practice should be provided for subtasks/steps of different difficulty levels.

G. Variable Class: Training Methods (Spacing of practice trials)

1. Separating practice trials by one-day intervals had a dramatic effect on retention. Students, after 14 days, were able to troubleshoot generators much faster when they had been trained with spaced practice than with massed practice. The spacing effect, however, was not evident for the simpler task of assembling/disassembling the M60. [See Bahrick, 1979 for supporting data on one-day spacing.] (Rose, McLaughlin & Felker, 1981)	1. Harless does not deal at all with the problem of massed vs spaced training. We might add some rules on spacing. e.g. for tasks with serious performance deficiencies or greatest predictable forgetting, repeat the isolated practice trials over several days.	1. Since spacing could be a logistic problem, can we develop general rules about which tasks to space? Can we quantify the effect of spacing on the regression curves for skill retention?

N. Variable Class: Training Methods (Mastery vs. Proficiency, i.e. effects of overtraining)

1. Three repetitions of a task beyond the priming stage of training (i.e. familiarization, explanation, illustration) appear to be optimal for maintaining skills. You don't seem to buy significant improvements in speed or accuracy beyond three repetitions. Rose et al. (1981) cited results for a variety of tasks: M60 assembly/disassembly (Schendel & Hagman, July,1980), boresighting (Goldberg et al, 1981), and alternator/ generator testing (Hagman et al., May, 1980a).	1. The finding suggests that you may want to repeat the isolated practice exercise (in the Harless Method) three times to optimize skill retention. Clearly you'd have to write some prioritizing rules for when to do this, since you would not have the time to repeat every integrated practice exercise.
2. Overtraining by one trial on one piece of equipment can help the soldier to transfer to a second type of equipment, but interferes with transfer if the student repeats the exercise more than once. (Hagman, May 1980a, Pages 13 and 15). But, if the student can practice the same task on three different pieces of equipment then he will be more able to transfer the training to yet other equipment. (Rose, McLaughlin & Felker, 1981)	2. If you're concerned about soldiers being able to transfer their skills to different types of equipment repeat the isolated exercise on one piece of equipment only once or twice. Alternative: if more than one type of equipment is available (e.g. two different types of generator) have student repeat the isolated exercise on the different types.
3. Don't necessarily train only for highly accurate performance. Train for adequate accuracy and use the time saved for training other important aspects of the job, such as speed of performance. (Training for highly accurate or highly speeded performance are forms of overtraining. (Schneider, W., 1985)	3. The Harless training procedures have the effect of limiting training to adequate performance rather than allowing overtraining.

4. Rose et. al support and extend Schneider. They found that over-training on one form of a system inhibited performance on other forms of the same task. However, they also found that overtraining in specific ways improved retention and generalization.

I. Variable Class: Training Methods (Additional Refresher Training) (Rose, McLaughlin & Felker, 1981)

1. Refresher training for disassembly of an M60 machine gun was very effective in reducing errors after an 8-week interval following AIT. (57% fewer errors). But, overtraining at the school was at least as effective (65%). [Schendel & Hagman, July, 1980].

2. Shields, Joyce, and VanWert (1979). For chaparral operations, refresher training did not yield better performance than no-refresher training. However, the skill decay curves for these tasks are very shallow, compared to the skill decay curves for assembly/disassembly which are very steep.

1. and 2. These two studies reinforce the potential value of adding to Harless some rules which use the skill decay curves to decide which tasks to emphasize with special techniques. e.g. If the task has a steep decay curve, then either over-train the task or refresh. If you do not overtrain such a task then tag it for refresher training in the unit.

J. Variable Class: Training Methods (Variety of training materials) (Farr, 1986)

1. Intra-task and contextual interference make initial learning more difficult but improve retention and transfer. (Battig, 1979; Shea & Morgan, 1979, as cited in Farr, 1986))

1. Teach hard discriminations where possible. Look for discriminations in what might otherwise look like simple chains. e.g. the task analyses that appear in the TMs are usually shown as lists of steps but if you did the Harless analysis you'd discover discriminations and generalizations. 1. Need to translate the basic findings into maintenance training operations and then do a controlled test. e.g. find ways to build in decision points to what is otherwise represented as a chain of steps, and then test training effectiveness with and without the decision

	points.	
2. Hybrid way to build contextual interference works even better than ways in item 1 above. Specifically Bransford's research (cites Nitsch) on concept learning showed that if you start with "same context" examples and then shift to "different context" examples, students will acquire easily, but also retain and transfer well. (Bransford et al. 1979, as cited in Farr, 1986; Tyler, 1979)	2. In priming generalizations, use examples that are closely related to the demonstration (positive and negative instances), then bring in examples that are very different (again use positive and negative instances).	2. Same as above. We need to find a way to translate the basic research operations into *maintenance training* regimens and then test whether the conclusions from basic research hold for maintenance training.
3. Vary aspects of the training that vary on the job. Train on the variety of equipment that will be available in the field. (Schneider, W., 1985)	3. The Harless job analysis procedures emphasize determination of all aspects of the job to be trained.	3. Is the concept of training maintenance on just three systems more efficient than Schneider's prescription of training on all systems? Hagman's data say "yes," but this finding should be confirmed with further research before it is considered a valid finding.
4. Finding from Hagman studies is that soldiers remember and transfer a skill better when they have practiced *the skill on different* types of equipment for 3 times beyond proficiency and the practice sessions have been spaced one day apart. Single task repetitions, on the other hand, i.e. overtraining with the same equipment can interfere with generalizing to other equipment. (Rose, McLaughlin & Felker, 1981)	4. Harless deals with this situation, though his *rules* may have to be embellished somewhat or emphasized a bit more. e.g. He specifically encourages you to identify the need to generalize. Generalization is one of his three main behavior paradigms. But he doesn't explicitly deal with situation where one task may have to be applied to different pieces of equipment. And, perhaps it would be useful to add this to Harless either as an illustration or a specific set of rules. Could be an interesting challenge to build a priming exercise that applies one task to different pieces of equipment. Might handle *this through the diagnostic testing* within the Priming exercise. Or might work in some rules about using job aids to handle generalization problems. Might also expand the definition of generalization by setting up tasks designed *specifically for coping* with the variety of conditions under which a task might be performed.	

K. Variable Class: Training Methods (Presentation vs. Practice)

1. General conclusion: If a POI emphasizes practice over presentation, students will retain their skills better, even if they are not given feedback after the exercise. In a study by Hagman (Jan, 1980), students were trained to move a sliding lever a specific distance with the help of, a notch in the slide track (presentation condition) and then allowed to "practice" without the help of the notch. Some "practiced" (i.e without the notch) 12% of the time, others 50 % of the time, and still others 87% of the time. As the ratio of practice to presentation increased so did skill retention. (Rose, McLaughlin & Felker, 1981)

1. The 12 percent condition is closest to how BKS is taught. BKS, therefore appears to violate research conclusions and it clearly violates the Harless method. Harless is closest to the 87 % practice condition in the Hagman study, since Harless encourages a small amount of priming (roughly equivalent to the presentation condition). Here is another instance in which research supports the Harless rules.

1. The problem here is that none of the tasks studied are closely related to anything that maintainers do and therefore this variable may be a good candidate for TTFA-Aberdeen research. e.g. for the tasks identified by ASA as performance problems, what ratio of lecture to practice or individual exercise will work best. In view of the amount of time spent in lectures and the extent to which this violates both Harless practice and ARI research, a repeat of the Hagman work for 63W10 could have high pay-off.

L. Variable Class: Training Methods (Deep processing: Overview)

1. The more meaningful and distinctive a cue is the more effectively it triggers recall and transfer. A number of operations are identified by Farr which add information or distinctiveness. e.g. improve definition, study several dimensions of the cue, add more information, provide explanation, use analogies, find synonyms, increase the mastery criterion, degrade the task (i.e. create puzzles). (Farr, 1986)

1. Harless has some rules which encourage deep processing, e.g. use of mnemonics, but he doesn't emphasize them much because of his extreme orientation towards performance oriented training. He doesn't seem to be much into explaining the "whys" and "wherefores". Perhaps we could emphasize this more in the prerequisite to priming section. Or, we could build in help routines which explain how things work, or consequences of poor performance. Possible addition: a rule which says that where cues are unfamiliar, make special efforts to define them either in prerequisite training or as part of the priming exercise. Another way to encourage deep processing is to build puzzle exercises into Harless. Have students identify a missing step or procedure, or missing part of a critical cue.

N. Variable Class: Training Method (Deep Processing: Semantic Coding).

1. The research cited by Farr reaffirms old wisdom that meaningful materials are remembered better than less meaningful materials. Basic operation used in this research was to present words to subjects and ask them increasingly meaningful questions about the word, e.g. lower case vs. upper case, word rhymes with ____, word does or does not fit a particular sentence. (Farr, 1986)

a. The more meaningful the question, the higher the recall. For sentence-fit questions, more complicated sentences yielded better recall than simple sentences. Multiple exposure to material results in significant improvements in recall. In other words recall depends both on how you study material as well as how many times you are exposed to the material. (Farr, 1986)

b. The more congruent the context, the higher the recall. (e.g. where a word fit a sentence it was remembered better than if it did not. (Farr, 1986)

c. Incidental learning was as effective for recall as was "deliberate" learning,i.e. it was how you processed the word which counted, not whether or not you knew you'd be tested on it. (Farr, 1986)

d. money incentive didn't make a difference. e.g. subjects didn't remember words better if they were paid more for accurate performance. (Craik and Tulving, 1975; Page 55 in Farr)

1a. and 1b. Harless suggests a number of ways to build prompting exercises. The research findings of 1a and 1b suggest an additional approach. If you want to teach technical terms like "volt" and "ampere" build a set of sentences using the terms and ask the student to indicate whether the term fits the sentence. Ask him to correct the sentence if it is wrong. Give the student about equal numbers of correct and incorrect sentences. Use each term once in a correct sentence and an incorrect sentence, then repeat the exercise but with different sentences.

Some deep processing procedures are already used in Phase 1 63W10. For instance instructors use probe questions but many Phase 2 graduates still don't know the difference between an ampere and a volt. It may be that the Phase 1 people have learned the difference but forgotten it by end of Phase 2. If so then "deep processing" techniques are only a small part of the solution to inadequate training.

N. Variable Class: Training Method (Deep Processing: Mnemonics)

1. A mnemonic is a character, word, sentence, or picture which helps a student remember facts, rules, or procedures. Mnemonics take the form of acrostics, metaphors (verbal or graphic), rhymes or combinations of these. (Farr, 1986)	1 - 4. Harless encourages the use of mnemonics, especially to improve discrimination training. The Japanese work on mnemonics supports Harless. Might extend Harless by recommending more extensive use of mnemonics to help teach procedures and rules.	
2. In American education, mnemonics have been used primarily to help recall facts, but the Japanese have used mnemonics (especially metaphors) extensively to teach rules and procedures in math, chemistry, physics, biology, spelling, and English. Anecdotal as well as research evidence indicates that the Japanese use of mnemonics (Yodai) is generally more effective than "conventional" methods of instruction. (Higbee & Kunihira, 1985, as cited in Farr, 1986)		
3. Characteristics of Yodai. Yodai uses language and pictures which are very simple and very familiar to the particular group being taught. Students don't have to memorize the mnemonic itself, because it is already part of the students knowledge. [Higbee & Kunihira, 1985, as cited in Farr, 1986]		
4. In contrast, ARI research on acrostics (to help trainees recall procedures for operating equipment) failed to support the value of mnemonics. However, the mnemonics were not simple or familiar. They consisted of sentences about military activity, e.g. "explosions usually terrify individual defenders although platoons rarely scare". This is not a mnemonic that rolls readily off the tongue. (Dressel, 1980)	4. Harless doesn't mention use of acrostics though he does tell you to use mnemonics when stimuli are unfamiliar or otherwise difficult, or when S - R connections are unnatural. The research on mnemonics prior to Dressel's study supports Harless [referenced in Dressel]. Rule: current Harless guidance, but add the following: use acrostics sparingly. Acrostics must be simple and catchy or many soldiers will not use them.	4. The conditions under which acrostics are effective training tools need to be determined experimentally.

D. Variable Class: Training Method (Effects of Theory and Understanding: Overview)

1. The general conclusion in Farr, Page, 76, is that students will recall and generalize procedures better if the students are taught "theory", e.g. taught the reasons for the procedures or how equipment operates. and/or have relevant prior knowledge. And, for complex, abstract topics, e.g. electricity, the proper use of analogies can increase problem solving skills. (1986)	1. & 2. The research suggests that the Harless method stresses task-specific training too much, and that it would be more effective if it paid more attention to explaining why tasks are done the way they are. Both theory and practice are important but theory should be very relevant to and closely supportive of practice. Trainers can't teach shotgun theory in hopes that students will transfer and generalize skill better. Instead, trainers should define the skills they want to shape and then decide what background or deeper understanding is necessary.
2. But the literature on functional context training says that background instruction (e.g. theory) must support and be integrated with practice if it is to be useful [Sticha, 1987]. Other literature including a study by Kieras and Bovair (1984), a study by Alexander et al. (1987) on general training in analogous reasoning, and an assessment of "new math" by Howson et al, (1981) support this conclusion. New math, for example, over-stressed *understanding at the expense of task* specific skills. Not surprisingly, students developed understanding without the specific skills.	
3. Training a conceptual understanding of a system does not assure that the trainee will develop proficiency on the job. (Schneider, W., 1985) Schneider's conclusion is supported by Kieras & Bovier, 1984.	3. Supports Harless. Harless emphasizes training only what is required by the job, thus he includes conceptual understanding only if it has been identified in the job analysis as a critical behavior.
4. There may be confusion between two concepts -- conceptual understanding of the hardware and conceptual understanding of the task performed with the hardware. The trainee may not need a conceptual understanding of the hardware, but only of those hardware functions he is responsible for as well as a conceptual understanding of the task he is performing on the hardware, which may be independent of the specific	4. The work by Kieras and Boviar (1984) suggests that it is a mistake to separate basic skill and knowledge training (BK&S) from MOS task training (phase 2 of the 63W10 course).

hardware.(c.f. Kieras & Boviar,1984.)

P. Variable Class: Training Method (Theory/Understanding: Analogies)

1. Analogies can be very effective, if students understand the analogous material, e.g. hydraulics can be effective for teaching electronics, but only if the student understands hydraulics. (Farr, 1986)

1. Harless doesn't teach the use of analogies as a training strategy. We could add this to the methodology with some rules, e.g. don't use analogies unless you're certain that students understand the analogous materials. Develop a short quiz to test for comprehension of an analog before you use it. Consider teaching analogous topics before the target topic. For example, if you're teaching both hydraulics and electricity, and you want to use hydraulics as an analogy for electricity teach the hydraulics first.

2. Analogies can be effective if objects and their relationships in the analogous subject are clearly parallel to objects and relationships in the new material. e.g the student has to be able to see clearly the similarity between the way electricity flows through a resistor and the way water flows through a constriction in a pipe, if the water flow analogy is going to be effective. (Farr, 1986)

2. Suggest to training developers who want to use analogies that they lay out a table similar to the one below which shows the connections between terms from hydraulics, the moving crowd analogy, and terms from electricity

Water Flow Models	Moving Crowd Model	Electrical Circuitry
Hydraulic system	race course	circuit
water	mice	electricity/electrons
pipe	wide corridor	wire
Pressure of water	pressure of mice	voltage
narrowness of pipe	narrowness of gate	resistance
flow of water	passage rate of mice	current

From Gentner and Gentner, 1983

3. Different analogies may be effective in different parts of a lesson. (Farr, 1986)

3. Use rules from whatever data or experiences are available, e.g. from Gentner and Gentner, 1983, we can cite the following:

TO TEACH EFFECTS OF	USE
1) Parallel batteries on voltage	Moving crowd analogy
2) Series batteries on voltage	Reservoir analogy
3) Parallel resistors on voltage or current	Moving crowd analogy
4) Series resistors on voltage	Pump analogy

Q. Variable Class: Training Method (Theory/Understanding: Prior Experience)

1. If students bring relevant background knowledge to the training situation or are given background knowledge in the form of advanced organizers, they will retain skills better even if original learning reached the same level with or without the background. (Gagne, et. al 1985). However, the background has to be very specific to the skills being learned. (Ausubel, 1961, as cited in Farr, 1986).

2. This conclusion has an interesting side effect. The ARI/AIR retention program suggested that there is a universal skill decay curve for each task taught to the same criterion level. The research on effects of prior knowledge indicate that there may be as many different decay functions as there are conditions of learning. This is practically as well as theoretically important. (Farr, 1986)

1. Validates Harless inclusion of a background section before the priming section and Harless encouragement of providing overviews of coming material before getting into the details of new material. Revision to Harless: emphasize value of relevant background instruction even more. Make a point of explaining its value and possibly come up with some rules of thumb for designing background and overview material, e.g introduce the concept of "advanced organizers".

R. Variable Class: Training Method (Theory/Understanding: Explanation)

1. If students are taught to understand how their equipment works, they will: a. learn operating procedures faster, b. remember them longer, c. work more efficiently, d. infer missing information much faster, and e. recover from problems more easily	1. Implication for current USAOCS training: The Kieras et al. paper is fairly direct and strong evidence that the USAOCS policy of teaching shotgun automotive theory in Phase 1 is a serious mistake. It also suggests that Harless extreme emphasis on task training may be a mistake. Harless could be improved if it said something about the value of "how-it-works" information to support procedures. He does make some provision for background explanation just prior to the priming exercises, but this needs to be emphasized more by explicitly teaching that explanation can make a significant difference to on-the-job performance. Could add some rules derived from the Kieras study.	1. We could well repeat something like the Kieras experiments at TRADOC installations, to see if his findings hold up in a more applied setting. The procedure would be to manipulate the amount and type of "BK&S" prior to giving hands-on training. One condition would represent the current practice of providing general engineering information. The second condition would involve providing very well focused information. (Farr, 1986)
2. But, explanation about how equipment operates is useful only if it directly supports the specific skills which students must learn in order to do a job. How-it-works knowledge is useless and inefficient otherwise.		
3. Worse yet, explanations that are poorly learned will lead to negative-transfer. Therefore how-it-works knowledge can be very superficial and incomplete and still be very effective. (Above conclusions derived from Kieras and Bovair, 1984, cited by Farr, 1986)		

S. Variable Class: Motivating the student (Schneider, W., 1985)

1. When training on training devices add simple cues to correct performance such as an interesting sound when the student performs correctly This procedure has reduced failure rates in day long, boring training sessions from 30 to 5%.	1. Schneider supports Harless's use of guided practice, rapid feedback, and short exercises.11. Identify cues to correct performance that maintain performance in long training sessions.	
2. "Maintain active participation throughout training on training devices. Active participation is enhanced if subjects need to respond every few seconds."	2. Schneider's recommendation supports Harless's workshop approach. Harless accepts less active participation than this, not requiring a trainee to respond for minutes. He	2. The amount of active participation required to maintain acceptable learning rates should be determined for the Army school situation, which can involve highly fatigued trainees.

	specifically allows for "passive" training, e.g. demo/explanation.	
3. Brophy and Good (1986) indicate that the rate of probe questioning by teachers is related to achievement. In one study 24 questions per 50 minutes led to higher achievement than 8 questions per 50 minutes.	3. The Harless Workshop recommends a probe question rate of one question per two minutes.	3. What is the optimal rate of probe questioning for TRADOC schools?