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Research Issues in Training Device Design: The Organization of a Data Base

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Training and Simulation Technical Area
Training Research Laboratory

U. S. Army
Research Institute for the Behavioral and Social Sciences

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This paper is an accumulation and categorization of training systems research issues which are critical in making training device design decisions. The training system research issues are organized around an Instructional Systems Development (ISD) type framework, and the research literature on these issues is reviewed. A means for accumulating new and existing data as well as accessing the empirically derived information and generating training device design guidance is proposed.

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Research Issues in Training Device Design: The Organization of a Data Base

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Training and Simulation

FOREWORD

The Training and Simulation Technical Area (Simulation Systems Design Team) of the Army Research Institute for the Behavioral and Social Sciences (ARI) performs research and development in areas that include training simulation with applicability to military training. Of special interest is research in the area of training device design requirements. Before the Army can develop and procure effective training systems, it should first determine the most effective and efficient design for those systesms. However, adequate guidance for determining these system designs is not currently available.

This report provides the foundation for a training system issues data base. Such a data base can support user-oriented guidance in the design of training systems.

User-oriented guidelines for making training system design decisions will facilitate the efforts of training device procurers such as the Army Project Manager for Training Devices (PM TRADE) and also instructional systems developers in the Army Training and Doctrine Command (TRADOC).

EDGAR M. JOHNSON
Technical Director

RESEARCH ISSUES IN TRAINING DEVICE DESIGN: THE ORGANIZATION OF A DATA BASE

EXECUTIVE SUMMARY

Requirements:

To contribute to the development of empirically based guidance for the design of training devices and training systems by: (1) accumulating and categorizing the training system research issues which appear to be critical in making decisions about training device design, (2) conducting an initial review and analysis of pertinent training device research, (3) proposing a means for accumulating new and existing data, (4) proposing a means for storing and accessing empirical information, and (5) proposing a method for generating empirically derived training device design guidance.

Procedure:

The paper is organized into four main sections: an introduction and statement of the problem, a discussion of how the data derived from investigations of training system research issues may be formatted and accessed by training developers via a proposed expert system, an Instructional Systems Development (ISD) based framework for organizing training system research issues, and a section which defines the research issues and reviews the literature,

Findings:

There is a vital need for empirically based guidance for the design of training devices and training systems. Current design procedures are too reliant on subject matter, expert opinion, or intuition. Existing data and new data can be accumulated into a master data base which may then be used as the foundation for an expert system for training device design guidance. The accumulation of training system research issues will serve as the conceptual organization of the data base and knowledge system.

Utilization of Findings:

This report may be used by researchers in planning for research on training system issues and for the preliminary design of training system design guidance packages.

RESEARCH ISSUES IN TRAINING DEVICE DESIGN: THE ORGANIZATION OF A DATA BASE

CONTENTS

	Page
INTRODUCTION	1
Purpose	2
Organization	3
FORMATTING AND ACCESSING A TRAINING DESIGN GUIDANCE SYSTEM	3
A Format for a User-Oriented Data Base	3
Accessing the Data Base	5
Structuring the Data Base	8
RESEARCH ISSUES IN ISD CONTEXT	8
DEFINITION AND ELABORATION OF RESEARCH ISSUES IN TRAINING DEVICE DESIGN	10
Training Needs Assessment Issues	10
Task Analysis	10
Media Selection	12
Trainee Characteristics	13
Training Strategy Issues	14
Training Device Design Issues	16
Training Device Fidelity Issues	16
Instructional Features Issues	19
Training Device Architectural Issues	22
Training Device Implementation Issues	23
User Acceptance Issues	23
Training Device Integration Issues	23
Noninstitutional Use of Training Devices	24
Issues in Training Effectiveness Assessment	24
General Training Evaluation Measurement Issues	25
Types of Training Effectiveness Assessment	27
Assessing Cost Effectiveness	32
Resource Requirements	34
SUMMARY AND RECOMMENDATIONS	34
REFERENCES	41
APPENDIX A: TYPES OF TASK ANALYSES	67

LIST OF TABLES

Table 1. Training system research issues 11

2. Representative training device design and training system theoretical and review articles 17

3. Representative training device design and training system empirical studies 18

4. Possible instructional capabilities of training devices 20

5. Representative publications which discuss training effectiveness analysis methodology issues 25

6. Research designs for determining training device effectiveness 29

7. Summary of training system issues requiring empirical investigation 36

A. Six approaches to task analysis and their main areas of concern 68

LIST OF FIGURES

1. A simplified training device research issue progression 4

2. A simplified overview of the ISD process 9

3. Different kinds of feedback (knowledge of results) 21

RESEARCH ISSUES IN TRAINING DEVICE DESIGN: THE ORGANIZATION OF A DATA BASE

INTRODUCTION

In recent years the Army, the other services, as well as private industry, have been forced to reevaluate the way individuals are trained. Economic constraints have made it unfeasible to use actual equipment as the backbone of instructional systems since actual equipment is often needed in the field and cannot be spared to use for training. In addition, new instructional techniques using training devices and simulators have afforded the opportunity to train tasks that are difficult or impossible to train using only the actual equipment. Many tasks are too dangerous to train on actual equipment or can only be exercised in a wartime environment. The tasks themselves have also changed in recent years. The use of high-technology equipment often enables easier operations but demands more difficult maintenance requirements. Instructional systems developers are now being called upon to upgrade their maintenance training procedures, possibly by using more sophisticated training devices and simulators. If the military is to use more training devices and simulators effectively, it must first specify the required characteristics of these training devices. Unfortunately, adequate guidance on how to produce these specifications is severely deficient.

The process of specifying training device characteristics is required by several Army regulations (e.g., AR 70-1, AR 71-9) and standardized in the Interservice Procedures for Instructional Systems Development (TRADOC PAM 350-30). Nevertheless, in actual practice, this process is often based on intuition and/or on budgetary constraints. Subject matter experts (SMEs) have no empirically derived data base for reasonable guidance on these matters and therefore often call for high fidelity when they generate the specifications for training devices. Based on the recommendations of SMEs, the individuals responsible for acquiring the training devices subsequently buy all the fidelity they can afford. There are at least four major problems with the current process of developing training device requirements (TDR): (1) There are excessive amounts of different kinds of documentation in the form of Army Regulations, Manuals, technical reports, and guidebooks, each purporting to give the final word in TDR development. (2) There is the problem of maintaining and updating these documents. As new TDR information, regulations, and techniques are developed they must be included in the morass of literature and then extracted by the user. (3) Even with all of this documentation, there is no specific empirically based guidance for making TDR decisions. (4) These three problems are exacerbated for the researcher who is attempting to support the training community by providing empirically based guidance. Not only must the researcher determine where guidance is needed, but also the type of guidance must be determined. With the current state of knowledge there are only a few empirically based guidance statements that the researcher can provide. The development of an empirically based guidance system to help in the specification of training devices would aid the decision processes of instructional system developers and procurement officials as well as improving the cost effectiveness of the Instructional Systems Development (ISD) process.

Purpose

The purpose of this paper is to contribute to the development of such a guidance system by accumulating and categorizing the training system research issues which appear to be critical in making decisions about training device design. In order to avoid needless duplication of effort, and to take advantage of the empirically generated information that already exists, an initial review and organization of pertinent training device research is also incorporated into this paper. In addition, a means for accumulating new and existing data and for accessing empirically derived training device design guidance is proposed. This paper is based on a three-faceted philosophy of training device design and training design development. This philosophy is not new but is believed to be the most effective approach to the development of training devices and systems.

The first facet of the philosophy is that training needs and training goals should be established prior to selection of any training device. The specifications for any training device should be driven by training needs and the best instructional techniques for reaching training goals. The characteristics of a training device, no matter how appealing, should not be the determining influence in instructional design.

The second facet of the philosophy refers to both the progression of learning and also the progression of training device design specification. As a general approach, both progressions should proceed from simple to complex. In learning, the trainee needs to move from a state of little experience with the task to one of more experience (Glaser, 1982). This progression can be most efficient if the tasks to be learned also move from simple to complex. Thus the trainee should first become familiar with the tools and equipment, and then move on to a more complete understanding of its operation (Kinkade & Wheaton, 1972; Fink & Shriver, 1978). In an analogous fashion, training device designers should start with simple, low-fidelity approaches and only add complexity or high fidelity as it is required to improve training. Many training device designs begin with as high a level of fidelity as possible and then fidelity is reduced until a level of affordability is reached. This approach must be reoriented to move from simple to complex training devices only when necessary to improve training.

Finally, the third and most important facet of the philosophy is that all ISD decisions should be both iterative and data based. By iterative, it is meant that no ISD decision should be final. It should rather be modifiable as more information is obtained during the course of the ISD process. By data based, it is meant that empirical data must be a primary factor in any training device design or training system decisions. Training system designers cannot afford to rely on intuition or input from subject matter experts who lack training expertise in designing training systems. The establishment and use of a data base and knowledge system which contains empirical data on all the research issued to be discussed and that provides usable guidance on those issues will be a valuable tool that will insure that the Army delivers the most effective training possible.

Organization

The remainder of the paper is organized into three main sections. In the first section we discuss how empirically derived data can be formatted and accessed by training device developers using the proposed knowledge base system. In the second section an Instructional Systems Development (ISD) based framework for organizing training system research issues is presented. This organization emphasizes the concept that research issues are not centered on any single variable or process but rather must focus on many interrelated processes linking a large variety of variables. In the third section the basic research issues are defined and the research literature on them is reviewed based on the ISD framework presented in the second section.

FORMATTING AND ACCESSING A TRAINING DESIGN GUIDANCE SYSTEM

In the following sections we will discuss many research issues that afford the opportunity for developing empirically based training device design guidance, as well as providing guidance in many of the other areas of the ISD process. In order to make such guidance usable by both the Army training community and the researchers who aid these decision makers, the accumulated data must be presented in a form that is both understandable by users and also relatively easy for the users to access. The first criterion for usability of a data based training design guidance system, understandability by users, involves the format and organization of the data base and knowledge system. The second criterion, accessibility, is mostly a question of how the data base is packaged and distributed to the prospective users.

A Format for a User-Oriented Data Base

Providing guidance for the decision maker in the ISD process is the bottom line goal of all research on training device and training system design issues. It is our opinion that the most effective method for meeting this goal is to provide empirically based information to the decision maker in a form that is readily understandable and usable in the ISD decision process. This can be most efficiently done by organizing the existing information and any new empirically generated data in terms of the decision steps involved in the overall ISD process. To a large degree, the decision questions discussed in this article address the decision points which would be used to organize this proposed data base. The implication is that the data base and knowledge system could thus be easily expanded or complemented by additional future research stimulated by the issues raised in this paper or by new user-generated issues. An example of this process of organization is illustrated by the progression presented in Figure 1. This progression begins with the initial user-generated question and ends with the empirically supported information provided to the ISD decision maker in answer to the question. In this example, the user is interested in knowing how much fidelity is needed in a training device used in training a specific task. This question is then framed as a basic research issue to be addressed by the research and development (R&D) community. This overall research issue concerns the effects of the interaction of level and type of fidelity and task type on transfer of training. This

TRAINING DESIGN GUIDANCE SYSTEM

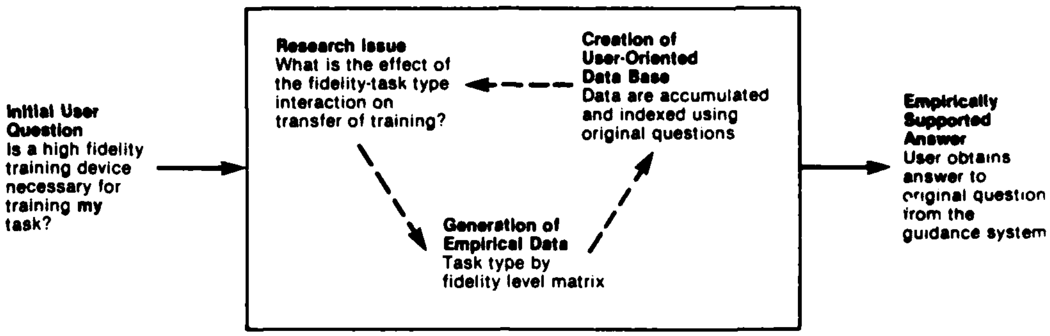

Figure 1. A simplified training device research issue progression.

issue encompasses many research areas that will be discussed later. To provide a comprehensive empirically based answer to the question, an adequate task taxonomy would have to be developed and applied (see Fleishman, 1982, for review), adequate empirical research into all of the various task-type and fidelity level combinations would have to be performed, and many of the other interacting variables would have to be checked. However, it does not seem reasonable to keep a training program developer waiting while a large data matrix is developed if our goal is only to use a small part of the matrix to answer the original question. A much more practical approach would be to identify the data necessary to answer the user's question and then check the previous research or perform new research in order to answer that particular question. Once the specific question is answered, the data base can serve as an archive to insure that future researchers will not have to duplicate efforts when a similar question is asked.

To some extent, the process of centering on the specific situation is the typical method used to provide information to the training program decision maker. An organized, accessible, and usable knowledge system can be built from the data existing in the reports generated in response to previous trainer's questions. Such a system would incorporate the data already accumulated in previous efforts. For example, the Air Force is in the process of developing a data base called the Integrated Perceptual Information for Designers (Boff & Martin, 1980). This effort centers on the perceptual information requirements for simulator displays and could be a major component of an overall ISD guidance data base. Another example is the Design of Training Systems (DOTS) project (Bellamy et al., 1974; Branch et al., 1976; Duffy et al., 1977; Miller & Duffy, 1975, 1976), which uses computer based mathematical models as tools to manage training organizations. The proposed system would serve ISD decision makers by making all of the existing ISD guidance information easily available as well as providing a framework for the generation of new data. The organization of the data base and knowledge system would identify the specific instances that have already been adequately investigated as well as identifying any areas that need further research. The primary user of the system would be the ISD decision maker, who would thus be able to use all of the empirically based information concerning the specific situation.

An additional benefit to both users and researchers would be that decisions made by training developers in those areas that have not been empirically investigated could also be included in the data base. Many design decisions are due to training device or actual equipment changes, new methods of training, or even instructor and trainee changes and require immediate action by the training developer. It is possible that these decisions and the information that supported the decisions could be entered into the data base in order to develop some form of "consensus" guidance for that situation. This approach would provide immediate SME guidance when empirical data are not available and would alert the researcher to areas requiring future empirical investigation. As a final note, this data base organization and utilization process could also allow identification of possibly less important situations, preventing unnecessary experimentation.

The various research issues which we will discuss do, to a large extent, reflect questions addressed by training developers almost every day. Each of these questions represents a specific instance in a progression like that in Figure 1. Once existing data have been accumulated and organized into an accessible, user-oriented knowledge system, the training developer's questions can be more easily addressed and answered. We realize that many of the practical questions must be asked and empirical data from previous research evaluated or new empirical data generated as the initial data base and knowledge system is created. The overall process is planned as an iterative process, as illustrated in Figure 1. As new data are accumulated on training questions, based on empirical research or on SME guidance, the data would be included as updated information in the system. A means of regularly reviewing and updating the data base and knowledge system would be established at its initial creation.

Accessing the Data Base

Just as important as the creation of a user-oriented training issues guidance system base is the necessity that the user be able to access it, that the system be eminently usable. Two candidate methods for ensuring that the system meets this criterion are a guidebook or a computer based system. Each of these approaches has pluses and minuses connected with its development and use. Guidebooks have commonly been used in various information utilization efforts prior to this, but only recently have efforts been made to automate these kinds of processes (e.g., the DSTIS project at the Army Training Support Center).

Guidebooks would certainly be the easier method to develop in the initial stages of the project. The information organization accumulated from existing research would be easily compiled and the early cross indexing of the guidebook would be based entirely on ISD decision steps. A guidebook may be readily accepted by the general training community, having been exposed to various types of guidebooks previously. There would be only minimal training involved in using a guidebook as there is a limit to the amount of specific indexing that can be used in a paper format. This training would most easily be presented in the guidebook itself. One area which can both hurt and help the effectiveness of the guidebook approach is that guidebooks typically require non-native users (one requires some degree of subject matter expertise) who can accurately interpret and integrate the information presented. In addition, as the guidebook development is completed and widespread use begins, guidebooks become more and more difficult to iterate and update. Typically, unless a formal mechanism for updates is established, the guidebook ends as a single edition publication, and if an update mechanism is used, some portion of the trainer's time is wasted in updating the book. Perhaps it is because of these problems and the previously mentioned interpretation difficulties that most guidebooks are rarely used in any rigorous fashion (Heeringa, Baum, Holman, & Peito, 1982) For these reasons, in spite of the initial ease of guidebook organization, we believe that a computer based approach would be much more useful in the long term.

First of all, the Army is beginning to use new computer based systems to control the data and paperwork flow required for the development of training devices and training systems. An example is the Devices and Systems Training Information System (DSTIS) implemented at Fort Eustis by the Army Training Support Center (ATSC) for TRADOC, DARCOM, and training school use. There is also a system under development for aiding training development during the concept formulation stage in the acquisition of a major weapon system. It is called the Early Training Estimation System (ETES) and is in the early stages of development at Fort Bliss. It will in part be based on comparing preliminary concepts with currently existing training devices and programs. These computer based systems are immature in that they are not yet fully implemented, although there are plans to link these systems together for information transmission and data sharing. Typically these systems are projected to solve certain specific problems that the different commands face, although the overlap of actual end-users is considerable. These systems, when integrated, would begin to solve the common Army-wide problems mentioned above, of tracking and updating the documentation and of including new guidance information while allowing easier end-user access. However, merely integrating the above systems will not solve the problem of utilizing empirical data and deriving guidance from that data. How to translate empirical data into user-oriented design guidance is not addressed by the types of developing systems mentioned above.

An automated training design guidance system presents a pattern that is opposite to the advantages and disadvantages of a guidebook. Early in the development of the system there will be problems of hardware and software selection. In compiling the data base the work required to adequately organize the existing empirical information will also be more extensive than that required by a simple guidebook. Constructing the rule based system for indexing the data base and organizing the guidance system (including changing the system in response to SME provided information) will certainly be more difficult than indexing a guidebook but will alleviate the problem of expert interpretation of research results by providing direct recommendations to the user. The rule system will thus aid and be improved by the SMEs while providing assistance to more naive users and facilitating the organization of a large body of knowledge.

The first step in the organization of an empirical data base is to identify the domain of information to be used. An organizing framework (see structuring section below) is used in this paper which supports the linking of many variables in the training device research domain. The second step is to review and reorganize existing literature for inclusion in the data base. This paper begins these two steps by providing a conceptual organization for the data base and initially reviewing the literature. The goal is a data base that can be manipulated in several ways: via standard keyword search, searches on training device type or other training variables, and by meta analysis programs (under development by the Army). Such data base manipulations will facilitate the delivery of design guidance based on empirical data on the training effects of different training system variables.

There is a considerable body of commonly held knowledge about training, as evidenced in Army regulations, technical reports, and guidebooks. There is also considerable knowledge, for example about fidelity requirements, that is buried in the literature and that can be extracted by meta analytic or delphic review. Existing knowledge would thus form the basis of a computerized guidance system for the early specification of training device requirements and would provide empirically based input to the immature Army systems mentioned above.

New computer techniques based on artificial intelligence research are providing better ways of dealing with knowledge (as the distillation of data). These expert systems are essentially computerized subject matter experts that operate in very restricted knowledge domains. The approach advocated in this paper differs from existing expert systems in that the proposed expert system will be based on knowledge drawn from an empirical data base of structured research, rather than on the knowledge and rules drawn from a group of acknowledged masters in the training field. This strategy is proposed for two main reasons: a group of acknowledged masters does not exist and a data base allows us to iterate and improve our knowledge as new data are developed. We can thus continually improve the guidance available from the system. The proposed knowledge system would draw on the empirical data base to provide reasoned conclusions from various analyses of the data. Such a system would furnish both direct guidance to training device and instructional system designers and also provide empirical and analytical support to training device and instructional system researches. The advantage of an iterative system is that short term guidance, based on existing knowledge may be provided fairly quickly. This guidance may be constantly improved as new data are developed from research and are incorporated into the system. We can thus have the best of both worlds: immediate guidance and continually improving guidance. The concept development for the data base and expert system is currently being studied at ARI.

Once these initial developmental problems have been dealt with, the computer system provides many unique and beneficial capabilities to the training community. The system will allow almost immediate updating based on new research results while alerting Army researchers to the most important problems faced by trainers in the field. In many ways the automated system would enable the trainer to become more of a researcher, being in direct and immediate control of continuing evaluations of their own programs. To some degree the amount of background work would be lessened for the trainer, in that a networked system would decrease the amount of manual updating required, as mentioned above, while possibly enhancing communications within the overall

Army training community. Finally, and perhaps most importantly in terms of future efficiency, computer equipment in the trainer's office should increase both quality and productivity while simultaneously easing the workload problems involved in maintaining and increasing Army training effectiveness.

Structuring the Data Base

In order to establish a data base that is both useful as the foundation for a rule based expert system and that is responsive to Army user needs, it is crucial that an appropriate conceptual structure for the data base be established. This conceptual structure will not only help accumulate existing data, but will also sensitize researchers to areas requiring new data.

As discussed above (see Figure 1), it is user questions which stimulate researchers to conduct their investigations. In the following sections, an Instructional Systems Design (ISD) framework is used to organize research questions. Such research questions require empirical data if they are to support the proposed data base and expert system. The accumulation of these research questions is based on an extensive literature review and the questions will serve as the basic conceptual structure for the training system data base and the knowledge system to be derived from the empirical data base.

RESEARCH ISSUES IN ISD CONTEXT

Instructional Systems Development (ISD) encompasses many diverse activities in addition to training device design (TRADOC, 1975). Tasks must be analyzed, training needs established, instructional media selected, programs of instruction established, and training effectiveness assessed. From a system perspective, all of these activities are equally as important as the design of training device characteristics. A change in output from any ISD stage will affect all others since they form an interdependent system. Likewise, the research issues which provide data for training device design may also provide necessary data for other ISD activities. When determining how research should be conducted, it is therefore important to recognize the many ways in which these data may be used, as well as their important derivative effects through the entire ISD process.

The interservice ISD procedures (TRADOC, 1975) depicts a 5-stage process. Other descriptions of ISD have used up to 20 steps (Mechner, 1981). The characteristic shared by all descriptions of ISD is the interdependency of its stages. The interdependency of the ISD process is illustrated in Figure 2, which presents a very simplified overview of ISD. This simplified diagram depicts ISD as a continuous process with four major sections (shown in boldface type). [illegible] stage view of ISD is focused on training device design. It is not presented as the best or the only version of ISD, but rather is presented as a means of organizing the research issues to be discussed below. Other approaches to ISD may have less emphasis on training devices; however, this paper is organized around training device design. Training developers concerned with other aspects of ISD must still deal with most of the research issues discussed below due to the systemic nature of training programs. Although iterative, the ISD process may be thought of as beginning with an assessment of training needs. Training needs are recognized when current training is determined to be inadequate either by assessing external threats (e.g., a new weapon system) or by making internal assessments of current training effectiveness. In any situation where current training fails to reach a desired level of effectiveness, a training need exists.

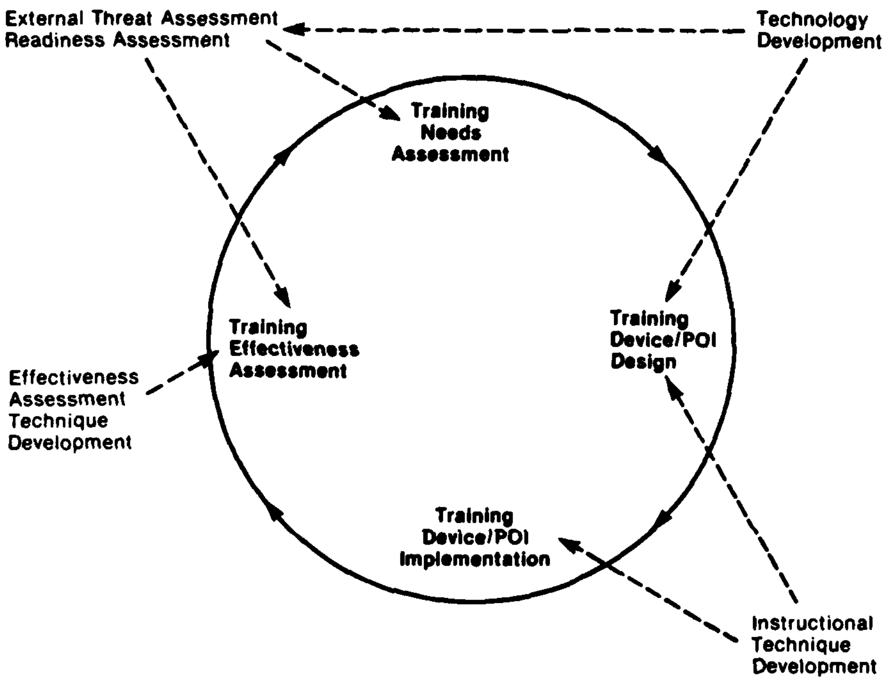

Figure 2. A simplified overview of the Instructional Systems Development process.

Training needs are typically met by changing the conventional instructional delivery system. Several methods may be used to change an instructional delivery system in response to established needs. One method is to adapt or alter the current program of instruction (POI). Another approach would develop a new training device and adapt the existing POI to the new device. Finally, both a new POI and a new training device might be developed concurrently. Any of these strategies leads to the determination of new training needs, and at this point the cycle begins again.

The ISD process is a dynamic, iterative one, and there are many research issues which may provide data for the necessary judgments at various points in the ISD process. The research issues discussed below are, in essence, structured ways of observing and recording the activities that connect the four sections depicted in Figure 2. A key point is that any research issue should be examined as it relates to each portion of the ISD process. In the following section, specific research issues are defined and a preliminary strategy for examining how each issue might influence training device design as well as the the other interrelated aspects of the ISD process is discussed.

DEFINITION AND ELABORATION OF RESEARCH ISSUES IN TRAINING DEVICE DESIGN

As stated above, no research issue exists in isolation if viewed from an ISD perspective. While this paper centers on training device design, it is impossible to discuss design without also discussing other aspects of the ISD process. Table 1 presents a set of training system research issues derived from the training literature which are believed to be major influences in the effectiveness of training. Each of the research issues identified in Table 1 will be discussed from two perspectives, first within the context of the major section of the ISD process with which it is most concerned and second from the perspective of its implications for training device design. It should again be emphasized that every issue interacts with all others and eventually it is the effects of all these interactions which must be determined.

Training Needs Assessment Issues

The first set of issues is concerned with assessing training needs. Before any modification of an existing training system or the creation of a new training system can begin, it must first be established that there is, in fact a training deficit. A task analysis is an important step in determining the existence of such deficits.

Task Analysis. There are various approaches to the analysis of tasks (Hays, 1981a), and each approach produces a different output depending upon how one wishes to use the analysis (see Appendix A for more detail). A task analysis which is to be used to develop proficiency tests for a training course will generate a different output from a task analysis intended to aid in training device design. For example, the developer of proficiency tests requires task analysis information on the indicators of successful performance (e.g., number of targets hit, time to repair a component, critical malfunctions, etc.). On the other hand, the training device designer is concerned with transfer of training from the training device to the actual equipment and therefore requires task analysis information about the controls, displays, and information required to complete the task. The designer then must decide how best to represent aspects of the actual equipment in the training device. A task analysis used in media selection will have still a third type of output. The training medium selected will depend on an assessment of training techniques and task criticality (Reiser et al., 1981) and therefore requires a task analysis output which addresses these requirements. If each user conducts a separate task analysis, much of the information in these analyses may be duplicated, although certain information that is needed for one kind of decision (e.g., media selection) will not be necessary for other decisions (e.g., proficiency test design) and therefore might be overlooked in a task analysis with a goal that is too specific.

Table 1

Training System Research Issues

ISD Section	Research Issues
I Training Needs Assessment	a. Task Analysis b. Media Selection c. Trainee Characteristics d. Training Strategy Issues (1) education vs. training (2) generic vs. specific training (3) whole vs. part task (4) error free vs. trial & error learning (5) self-paced vs. lock step training
II Training Device Design	a. Physical-Functional Fidelity Interaction b. Augmented Feedback & Instructional Features Issues c. Effects of Specific Architectural Features (1) 2D vs. 3D (2) trainee input devices (touch panel vs. key pad, etc.) (3) student station/instructor station ratio
III Training Device Implementation	a. User Acceptance Issues (1) instructors (2) trainees b. Integration of Training Device into Program of Instruction c. Noninstitutional Use of Training Devices and Simulators
IV Training Effectiveness Assessment	a. General Training Evaluation Measurement Issues (1) process vs. outcome measures (2) objective vs. subjective measures (3) criterion vs. norm referenced measures (4) internal and external validity b. Types of Effectiveness Assessment (1) establishment of proficiency standards (2) transfer of training vs. other measures (3) cost effectiveness vs. training effectiveness (4) short-term vs. long-term retention studies d. Resource Requirements

Research is necessary to determine just how task analyses are currently conducted and how their outputs are used. At this time there is no truly standardized task analysis methodology (Fleishman, 1982). Many task analyses are performed at the last minute to fulfill a procedural requirement (TRADOC PAM 350-30, 1975) or are shortcut to save resources (Branson, 1981; Kane & Holman, 1982). Surveys of training device procurements could detail who performed the task analysis, how the task analysis was accomplished, what types of information were generated, and how this information was used. A compendium of these survey data could then aid in specifying a standardized task analysis format and procedure. ARI is currently beginning this effort by surveying the front end analysis procedures used in the design of the bread board devices in the Army Maintenance Training and Evaluation Simulation System (AMTESS) program. A standardized task analysis format which includes all information necessary in all ISD phases would greatly reduce duplication of effort since repeated task analyses for various parochial decisions would not have to be conducted. Hays (1981a) suggests how the existing TRADOC task analysis format might be restructured to provide all this necessary information. The use of such a task analysis format by someone trained in the procedures required to conduct the analysis would provide savings of time and money for anyone who requires task analysis information. This is especially true in the case of training device design because decisions about the characteristics of the device must be driven in good part by information on what must be trained (Hays, 1981a).

Research is also needed to develop a workable task taxonomy (Fleishman, 1982). Classifying tasks into a manageable number of categories would greatly facilitate empirical investigations of how different tasks interact with training devices of different designs. Such a taxonomy would also aid in the process of developing generalized design guidance which could refer to task types rather than specific tasks. This research would be (1) analytic, surveying existing taxonomies and previous empirical research, (2) creative, developing improved taxonomies, and (3) empirical, validating any candidate taxonomies and generating empirical data on the interaction of task type with training device characteristics.

Media Selection. Even before decisions are made about what characteristics a training device should exhibit, the decision must be made to use a training device rather than some other medium of instructional delivery. There are at least 20 different instructional media types, ranging from actual equipment trainers (AETs) and simulators to films and classroom instructors, that are candidates for selection as part of a training delivery system (Reiser et al., 1981). This selection should be based on training needs (Caro, 1977a; Smode, 1971) and should be firmly embedded in the ISD process. Research is necessary to validate and possibly modify existing media selection models (such as Reiser et al., 1981; Anderson, 1976; Branson et al., 1975; Romiszowski, 1974; Braby, 1973; Bretz, 1971; Boucher et al., 1971; Campbell & Hughes, 1978) and also to extend the media selection models to include specifications for the characteristics of whatever medium is selected rather than stopping with the selection of a given medium. This is even more important for training devices and simulators, which are much more expensive and difficult to design, than for simpler instructional media such as slide projectors. Empirically derived data on the current uses of media selection models can tell us whether a consistently applied model could improve Army-wide training.

It may prove necessary to employ several types of instructional media at various stages during a program of instruction (Kinkade and Wheaton, 1972). If this is the case, then research will also be necessary to determine the training effectiveness of the various media mixes. Empirically derived data are required to determine the most effective use of instructional media at each stage of training and also to determine how the transition from one medium to another can be accomplished with the most effective training outcome. As will be discussed later, research is also needed to determine the effect of the interaction of media types and media mixes with trainee characteristics and training strategies. The AMTESS program is providing initial data on the mix of 3D mockups and 2D instructional delivery systems (e.g., CRTs or slide projectors).

Trainee Characteristics. Not every trainee comes to training with the same competencies, experience, confidence, or motivational structures. Depending on the task type, training strategy, and training goal, each individual's cognitive characteristics may influence the success of the instructional program for that person. Research could help to specify the appropriate training device characteristics and training strategies for different types of trainees. For example, a novice trainee may not have the experience necessary to benefit from all the cues available with a high-fidelity training device. On the other hand, an expert trainee may require a high-fidelity device to provide all the necessary information for learning the task (Martin and Waag, 1978a).

Research is also needed to determine what enabling skills are required for each type of training device (e.g., reading ability to communicate with a computer) and also to determine whether trainees should be selected for a training device or a training device designed for the trainees. If it is determined that trainee selection is the appropriate strategy, then further research will be required to validate current selection procedures. Many of these selection procedures use generic paper-and-pencil tests to assess trainee abilities. The problem is that the generic paper-and-pencil tests used to determine trainee abilities may have low correlation with actual skill performance (Foley, 1977).

Motivation is a characteristic that may have a strong influence on learning, retention, and performance. Schneider (1982) has advanced some specific guidelines for rapid training of subtasks to mastery levels and points out that a major variable for the success of the training process is the motivational level of the trainee. Research into trainee confidence has shown that as much as 58% of the difference between attainment scores and measured intelligence may be explained by the manipulation of this factor (Sylvester, 1970). Clearly there is a need for clarification of these motivational issues as they relate to military training. For example, how can a trainee's motivation be improved, how will improved motivation affect training and how is motivation affected by specific training device designs.

Another question that may influence training device design and selection is the effect of the trainee's learning set on training outcome (Monge, 1969). The notion of learning sets or learning to learn (Harlow, 1949; Harlow, 1959) suggests that learning a set of similar problems can result in the acquisition of a generalized skill that can later be successfully applied to new and different problems of the same class. Harlow's work was done with nonhuman subjects and subsequent studies have used human children as subjects (Rydberg & Arnberg, 1976; Fagen, 1977). To the authors' knowledge, there have been no studies which investigated the effects of learning set in a military context. How the trainee approaches the training situation may hinder or help the learning process. The trainee's knowledge, how that knowledge is organized and used, as well as the trainee's cognitive skills may have important effects on the success of the training program (Ausburn, Ausburn & Ragan, 1980). Research is required to define learning sets more clearly as well as to determine their effects on training.

There is some evidence to indicate that neurological organization in terms of hemispherical dominance is unimportant for procedural motor skills (Tyler, 1971). There may, however, be neurological differences that affect other types of learning and that would therefore influence acquisition of some of the more complex troubleshooting skills (Ausburn, Ausburn & Ragan, 1980). Empirical research in this area could clarify the relationship between neurological organization and specific training and task demands.

The need for mastery of complex troubleshooting skills has been identified by surveys indicating that there is a high degree of human error in maintenance tasks (Robinson et al., 1970; Orlansky & String, 1981b). As military systems become more complex, the cognitive demands on the trainee will also increase, as will the cost of errors. This increasing complexity in the military environment requires that many aspects of trainee characteristics and task requirements be studied in order for training to produce the best-trained persons for the job. Research questions should center on how the demands of various training device designs, interacting with trainee characteristics, affect task learning, transfer of training, as well as long-term retention and performance.

Training Strategy Issues. The recurrent theme throughout this paper is the interaction of all training system research issues. This point is made again in the discussion of training strategy issues. Once the task analysis is performed, the integrated process of training strategy development and media selection based on trainee characteristics and training needs can begin.

The first general question which must be answered in developing an overall training strategy is: Should the focus be on education, centering on teaching general principles, or should the focus be on training that provides only task-specific information? If the performance of the target task requires psychomotor skills, the program of instruction should include spatial and kinesthetic training that at least approximates the psychomotor skills needed for criterion performance. However, if the target task or set of tasks covers variable situations that require general problem-solving skills, to some degree the training program should be a general, discovery-oriented curriculum that enhances understanding and strategy acquisition (Singer, 1977). In many maintenance tasks a major portion of the training requirements involves the correct use and basic understanding of technical manuals, which may be best taught by general instruction and practice with common information-handling tasks (Hogan, 1978). If entry-level people are lacking in necessary skills, then perhaps a general educational program oriented toward generic tasks should precede training for more specific tasks.

A second question which should be addressed is related to the issue discussed above: Is it more effective to train for generic tasks (e.g., tasks applicable to all types of automotive engines) or is it more effective to train for specific tasks (e.g., tasks applicable only to a single engine type)? The underlying psychological issue concerns transfer of training. Empirical research can determine whether skills learned on generic tasks transfer to specific tasks and vice versa. If there is a high degree of transfer, then other factors (i.e., cost) can be used to decide on what training strategy to develop. If the criterion task demands on the trainee cover a class of equipment, or transfer from the specific task training is low, then it may be more effective and efficient to use a broader-based generic training approach. It may also prove effective to provide an instructional progression from generic to specific tasks. It should be evident that a thorough task analysis and training effectiveness assessment program is essential to aid in making these training strategy decisions.

Within an instructional program that trains multiple tasks, a third basic question concerns whether to train whole tasks or part tasks. Very few tasks are simple enough to be taught from start to finish without confusing and/or overloading the naive trainee. Therefore many tasks should perhaps be dismantled into coherent subtasks for the purposes of training. However, if the organization or interrelation of the subtasks is very high and the whole task is not overly complex, then perhaps the task should be taught as a whole (Blum & Naylor, 1968). Decisions about how best to teach various task types should be determined empirically.

A fourth general question that must be answered in the development of a training strategy concerns the pacing of the overall instructional program. The two basic approaches to instructional pacing are lock step (time based) and self paced (performance based). Some research suggests that a standardized, lock-step training program is inefficient in that the training forces some large percentage of learners to be overtrained in order to bring a majority (or all) of the learners up to some criterion performance (Lawrence, 1954). One conclusion from this research is that some form of self-paced or mastery training may be more desirable (Bloom, 1974). On the other hand, the resource constraints, in terms of number of instructors and instructor time, has led some Army schools to require lock-step instruction (e.g., the Army Air Defense School was forced to go to lock-step because of lack of instructors). The decision to go lock step or self paced must be based on several factors: a) cost--whether one form of instruction is more cost effective both in terms of monetary and personnel costs; b) performance--whether all students must reach the same level of proficiency or whether some range of skills is adequate; c) transfer--whether the transfer to the criterion task is facilitated by one form of instruction over the other. Empirical data are required in order for the Army to make truly informed decisions on these issues.

One additional question that must be answered when designing a training strategy is whether during training we allow the trainee to make mistakes (trial-and-error learning) or whether we mitigate his probability of making mistakes (error-free learning). Training devices can be designed to guide and control every response made by the learner or they can allow the trainee to make mistakes in the course of instruction. If the target task is normally performed using fixed responses and has built in prompts and cues, then a guided learning approach in which trainees are not allowed to make many errors may be the best technique (Singer, 1977). On the other hand, if problem solving is a major component of the criterion task, then there are indications that a high-error-rate, discovery-based technique may be more appropriate (Singer, 1977). In any case, there is a considerable base of research on this issue, and the task is one of applying what is known to the integration of training device design with training strategy.

Each of the above questions must be answered in the context of the task to be trained and the characteristics of the trainees as well as the characteristics of the training device to be employed. Research is necessary to establish the strengths and weaknesses of each training approach so that informed decisions can be made about training strategies.

There have been attempts to develop learning guidelines and algorithms for training various types of tasks (Aagard & Braby, 1976; TRADOC, 1975). Research is needed to validate these guidelines and also to determine how they are currently being used and how they might be used more effectively.

Training Device Design Issues

As previously noted, the focus of this paper is on training device design issues. In each section of this paper, issues are related to device design, even if their main area of concern is another aspect of ISD. In this section, however, we discuss research issues that are directly relevant to training device design. Table 2 is a listing of theoretical and review articles which address training device design issues by examining the role of training device fidelity and other training system issues. A similar listing of empirically based studies is provided in Table 3. It should be remembered that the factors which are examined under the rubric of training device design issues will be modified by the interaction with variables studied under the rubric of other research issues, which are less directly relevant to training device design and which are discussed in other sections of the paper.

Training Device Fidelity Issues. The term fidelity has been used differently by many authors (Hays, 1980). For our purposes, training device or simulator fidelity refers to the degree of similarity between the training device and the actual equipment. Fidelity, as we define it, has two components: physical similarity (how the device looks) and functional similarity (how the device works). Most studies of the effects of fidelity have compared whole devices rather than systematically examining the interaction of these two aspects of fidelity (see Table 2). It is likely that physical and functional fidelity are complexly related since change in one will to some degree affect the other, but not necessarily in a linear fashion. It is more likely that the two aspects of fidelity are analogous to the two aspects of color: brightness and hue. When either aspect of color is changed, one's perception of the other aspect is also changed (Schiffman, 1976). Systematic research is needed to determine how the relative values of each aspect of fidelity interact with other training system variables to produce various degrees of transfer of training. Some of the training system variables believed to interact with fidelity are task type, task difficulty, required skills, trainee sophistication, stage of training, training context, integration of training devices into programs of instruction (POIs), user acceptance, and use of specific instructional features (Hays, 1981a). Current efforts (Baum et al., 1982; In press) are laying the

Table 2

Representative Training Device Design and Training System Theoretical and Review Articles

Area of Flight Simulation	Areas Other Than Flight Simulation
- Adams, J. (1957)	- Adams, G. (1977)
- AGARD (1980)	- Adams, J. (1979)
- Albery, Gum & Kron (1978)	- Baer, Jones & Francis (1980)
- Bailey & Hughes (1980)	- Barrett (1971)
- Caro (1970, 1973b, 1977a, 1977b, 1979)	- Battelle (1982)
- Condon et al. (1979)	- Beck & Monroe (1969)
- Cream, Eggemeier & Klein (1978)	- Blaiwes & Regan (1970)
- Cyrus (1978)	- Brock (1978)
- Demaree et al. (1965)	- Clark & Gardner (1977)
- Eddowes & Waag (1980)	- Fink & Shriver (1978a, 1978b)
- Huddleston & Rolfe (1971)	- Freda (1979)
- Huff & Nagel (1975)	- Gerathewohl (1969)
- Iffland & Whiteside (1977)	- Hall, Lam & Bellomy (1976)
- Isley et al. (1974)	- Hall, Rankin & Aagard (1976)
- Larson & Terry (1975)	- Hays (1980, 1981a, 1981b)
- Martin (1981)	- Hogan (1978)
- Prophet, Caro & Hall (1972)	- Hopkins (1975, 1978)
- Rolfe & Waag (1980)	- Hritz et al. (1980a, 1980b, 1981, 1982)
- Roscoe (1976)	- Kinkade & Wheaton (1972)
- Semple (1981b)	- Knerr, Simutis & Johnson (In press)
- Valverde (1973)	- Malec (1980)
- Waag (1981)	- Micheli (1972)
- Whiteside (1977)	- Miller, G. G. (1974)
- Williges, Roscoe & Williges (1973)	- Miller, K. E. (1980)
- Woomer & Williams (1978)	- Montemerlo (1977)
	- N.T.I.S. (1982)
	- Orlansky (1981)
	- Payne (1982)
	- Purifoy & Benson (1979)
	- Semple (1974b)
	- Smode (1971, 1972)
	- Smode & Hall (1975)
	- Spangenberg (1976)
	- Weitz & Adler (1973)

Table 3

Representative Training Device Design and
Training System Empirical Studies

Area of Flight Simulation

Motion Cues
- Bray (1973)
- Irish & Brown (1978)
- Irish & Buckland (1978)
- Jacobs (1975)
- Jacobs et al. (1973)
- Koonce (1979)
- Martin & Waag (1978a, 1978b)
- Nataupsky et al. (1979)
- Pohlman & Reed (1978)
- Roscoe & Williges (1975)
- Ruocco, Vitale & Benfari (1965)
- Ryan, Scott & Browning (1978)
- Woodruff et al. (1976)

Instrument/Procedures Training
- Bailey, Hughes & Jones (1980)
- Bickley (1980)
- Biersner (1976)
- Brictson & Burger (1976)
- Browning et al. (1977)
- Burger & Brictson (1976)
- Crosby (1977)
- Crosby et al. (1978)
- Demaree, Norman & Matheny (1965)
- Ellis et al. (1968)
- Goebel, Baum & Hagin (1971)
- Hagin, Durall & Prophet (1979)
- Holman (1979)
- Irish et al. (1977)
- Isley (1968)
- Isley et al. (1968)
- Krahenbull, Marett & Reid (1978)
- Pitrella (1974)
- Prophet & Boyd (1970)
- Provenmire & Roscoe (1971, 1973)
- Randel et al. (1981)
- Reicher et al. (1980)
- Reid & Cyrus (1974)
- Smith et al. (1974)
- Weitzman et al. 1979)

Areas Other Than Flight Simulation

Procedural Tasks
- Bernstein & Gonzalez (1969)
- Cox et al. (1965)
- Crawford et al. (1976)
- Grimsley (1969a, 1969b, 1969c)
- Grunwald (1968)
- Johnson (1978)
- McGuirk, Pieper & Miller (1975)
- Mirabella & Wheaton (1973, 1974)
- Rigney et al. (1978a, 1978b)
- Wheaton & Mirabella (1972a, 1972b)
- Wheaton, Mirabella & Farina (1971)
- Wright & Campbell (1975)

Operations Tasks
- Blaauw (1982)
- Finley, Rheinlander & Thompson (1972)
- Goldberg (1980)
- Goldin & Thorndyke (1982)
- Gray (1979)
- McKnight & Hunter (1966)
- Puig (1972)
- Rose et al. (1976)
- Semple (1974a)
- Spangenberg (1974)
- Wagenaar (1975)
- Wheaton et al. (1976c)

Psychomotor Tasks
- Baum et al. (1982, In press)
- Reidel, Abrams & Post (1975)

Troubleshooting Tasks
- Steinemann (1966)

Perceptual Tasks
- Prather (1971)
- Prather, Berry & Jones (1971)

Avionic Maintenance
- Baum et al. (1979)
- Biersner (1975)
- Cicchinelli (1979)
- Cicchinelli et al. (1980, 1982)
- Cicchinelli & Harmon (1981)
- Goett, Post & Miller (1980)

foundation for this systematic research. In this effort, physical and functional fidelity are separately manipulated to determine their relative contributions to training effectiveness in a psychomotor task. This research uses an ordinal measurement of physical and functional fidelity (Hays, 1980). Future research may use these ordinal fidelity metrics or develop other fidelity measures. Future efforts will also investigate other task types in addition to the interaction of fidelity with other training system variables.

Areas other than military training may provide insights into fidelity decisions. For example, the area of sports training has many useful procedures for training tasks that may be similar to tasks in the military (Rodionov, 1971). More traditional academic areas, such as tracking research (Poulton, 1974) may also provide insights into fidelity decisions. Experiments which focus on tracking but which also use devices of various configurations for training may be reanalyzed in order to gain new information for making decisions about training device fidelity. Research which investigates these other areas would be a useful complement to traditional fidelity research.

Instructional Features Issues. During a recent workshop on simulator fidelity (Hays, 1981b), two divergent viewpoints emerged. One view was that fidelity was a very important issue while the other was that the important issue was what instructional features should be incorporated into a training device. Such instructional features might consist of capabilities such as those listed in Table 4.

One instructional feature that deserves considerable attention is the capability of providing augmented feedback or knowledge of results. Feedback refers to information presented to the trainee about the adequacy of his or her performance. Feedback may be used by the trainee to guide ongoing behavior or to improve the next response (Holding, 1965). Miller (1953) distinguishes between these two uses of feedback by referring to them as action feedback and learning feedback respectively.

Holding (1965) makes further distinctions between types of feedback. The following is based on his discussion. Feedback may be intrinsic, present in the usual form of the task, or artificial (also called augmented), in the form of extra information added in for training purposes. Furthermore, augmented feedback may be concurrent or terminal. Concurrent feedback is information which is present all the time a person is responding, as in watching a pointer while adjusting a control knob. Terminal feedback is information which arises as a result of a completed response like the score of a dart throw. Likewise, intrinsic feedback may also be either concurrent or terminal. Most of the distinctions shown in Figure 3 may also be subdivided. Only one set of branches is shown for the sake of clarity. Both terminal and concurrent feedback may be immediate or delayed. These types in their turn may be verbal or nonverbal. Either of these types may be given after each response as separate knowledge, or else accumulated over several attempts and presented at the end of the series. There is a substantial body of literature on the effects of these various types of feedback (see Holding, 1965 for a review).

Table 4

Possible Instructional Capabilities of Training Devices
(Sources: Miller et al., 1977, and Hritz and Purifoy, 1982)

1. Freeze Capability. Under certain conditions such as trainee error, the device can freeze an instructional sequence.

2. Restart/Resequence Capability. The trainer has the capability to restart an instructional sequence at any point.

3. Malfunction Selection. The trainer can provide simulated malfunctions chosen by the instructor.

4. Sign-in Capability. Trainee can sign in on the device at any authorized time after providing specified information (passwords, etc.) to the device.

5. Number/Quality of Responses. The device can record, save, and display both the quality and quantity of trainee responses.

6. Internal Monitoring of Instructional Features. The device can monitor specified variables and/or responses for specific actions (e.g., device freezes if designated monitor reads in upper 1/2 of scale or device begins providing altered feedback if a designated control is activated).

7. Augmented Feedback. Under specified conditions or schedules the device can enhance the feedback received by the trainee.

8. Next Activity Features. Introduction of the next activity can be linked to specific trainee actions by the instructor.

9. Stimulus Instructional Features. The instructor/course developer can specify the rates and characteristics of stimuli presented to the trainee.

10. Cue Enhancement Features. Device can enhance specified cues during training exercises.

11. Automated Demonstration. Preprogrammed scenarios presented for trainee observation provide the trainee with a model of expected performance or the consequences of some critical action.

12. Record/Playback. A demonstration technique that may be used to replay portions of trainee's behavior. Often used to review critical errors.

13. Adaptive Syllabus. Techniques for computer control of trainee progression based upon performance. The training scenario is varied as performance improves.

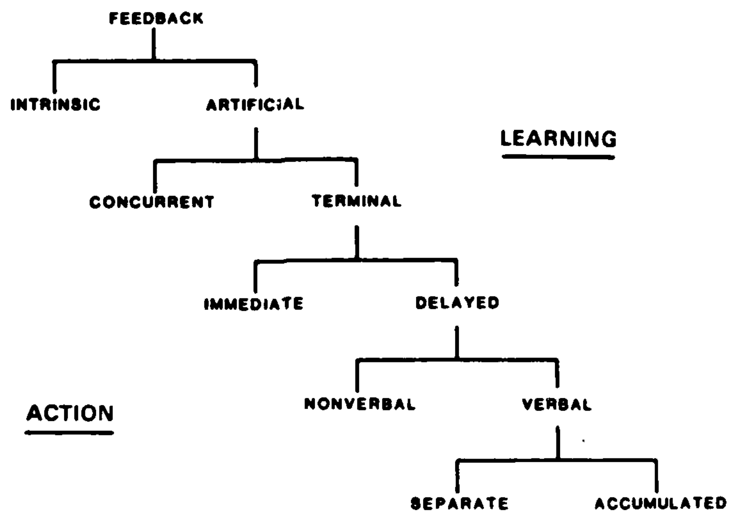

Figure 3. Different kinds of feedback (knowledge of results). (Source: Holding, 1965)

Boldovici (1983) discusses the dimensions of feedback in terms of changes in the salience of stimuli. He characterizes feedback as a means of altering the salience of the stimuli that initiate performance or increase the potential reinforcing value of stimuli that maintain performance. Boldovici first distinguishes between augmenting and supplementing feedback.

> Augmenting means increasing the value of a dimension of the signal--its size, brightness, or frequency of appearance. Supplementing means adding a new dimension to the signal; a flashing light indicating that the main gun safety switch is in the Fire position is an example. (Boldovici, 1983)

Boldovici then discusses how feedback may be altered either by attenuating or masking the noise in which it is embedded.

> Attenuating means decreasing the value of a dimension of the noise--its size, brightness, or frequency of appearance for example. Attenuating is essentially the opposite of augmenting, applied to noise. Masking means adding a new dimension to the noise. Tones introduced into the ears of people with tinnitus, for the purpose of reducing or cancelling "ringing" exemplify masking (Boldovici, 1983).

The main problem with using any of these techniques in training is that they may produce a "crutch effect" when transferring from the practice to the criterion environment. In other words, the trainee may come to depend on the altered stimuli in the training environment and then when the criterion environment does not provide such altered stimuli, performance may suffer. One means of overcoming the problems associated with the crutch effect is to gradually fade the altered stimuli during the course of training until criterion stimuli levels are reached.

Research is needed to determine the appropriate times to use altered stimulus salience in training and also when and how to minimize crutch effects. Boldovici (1983) reviews some of the research bearing on these questions. Research is also needed to investigate the training effects of other types of instructional features. Such data will enable training equipment designers to include only those instructional features that facilitate transfer of training and exclude features that have only cosmetic appeal but do little to enhance training effectiveness.

Training Device Architectural Issues. Data are needed on the effects of specific architectural features of training devices. For example, research could be conducted contrasting the training effectiveness of hands-on practice using a 3D versus a 2D medium. A 3D practice medium would allow the trainee to exercise the motor skills involved in the tasks while a 2D practice medium (such as a CRT touch panel) would only afford practice on the functional aspects of the task. Cicchinelli and Harmon (1981) made performance and cost comparisons among a 3D simulator, a 2D simulator, and the operational 6883 F-111 Converter/Flight Control System maintenance test station. No significant differences in student performance, as a function of training device employed, were found. However, actual equipment costs were found to be twice as high as for the 3D simulator. The relative cost effectiveness of the 2D and 3D simulators were not known at the time the article was written. Decisions on which type of "hands-on" practice medium to incorporate into a training device should be based on this kind of empirical data on the effectiveness of different simulator architectures.

Another architectural feature which requires an experimental assessment to determine its effectiveness is the mix of student and instructor stations. Is it more training-effective to have one student station per instructor station or can one instructor station monitor several student stations? Related to this question is whether more than one student should interact at a student station at one time. Answers to these questions will provide not only training device design guidance but also guidance in the development of programs of instruction (POIs).

Still another architectural feature issue is the method of trainee-device interaction. Seibel (1972) discusses a wide variety of alternative means for entering data. These range from keyboards, levers, switches and dials, to light pencils, and handwritten or voice inputs. The choice of when to use a specific type of input device depends on (a) the characteristics of the data to be entered, (b) the design of the data entry device and (c) the characteristics of the operator. Although Seibel's discussion is not about training devices, the same considerations apply in the training environment. Data on the training effectiveness of each possible input medium are required before informed decisions about the incorporation of a specific trainee data input feature into a training device can be made.

Training Device Implementation Issues

Any training device, no matter what its design, must be used if it is to provide training. An important aspect of the ISD process is therefore the implementation (installation and use) of the training device. The first set of issues in this context focuses on the general acceptance of a training device.

User Acceptance Issues. No training device can provide effective training if it is not accepted and used by an instructor. There are cases in which training devices are not used or are underutilized (Caro, Shelnutt & Spears, 1981; Mackie, et al. 1972). There are also cases in which the instructional features of a device are not used (Semple, 1981a). Often this lack of instructor acceptance or use can be attributed to the lack of fidelity in the device. Instructors know the real equipment better than they know instructional techniques and therefore may misjudge a device if it does not have "enough" fidelity. In other cases, the instructor is not fully trained on the instructional features of the device. This point is made by Caro, Shelnutt and Spears (1981) when they draw the distinction between acceptance of a device as it is used and acceptance of a device as it was designed to be used.

Only a few studies have addressed the acceptance issue (Biersner, 1975; Stoffer et al., 1980). These studies, although acknowledging the importance of user acceptance, do not systematically study the training effects of nonacceptance. It is therefore essential that additional research be conducted to determine all the relevant dimensions of instructor acceptance of a training device. Once these dimensions are determined, specific instructor training procedures can be developed to aid in the operational installation of a new training device. An instructor training procedure to counteract specific misperceptions about training devices (e.g., that high fidelity is essential) would do much to improve the ease and efficiency with which a training device is implemented and used.

Analogous to instructor acceptance is the issue of training device acceptance by trainees. Though trainees do not have the experience with actual equipment that instructors do, they still need a certain degree of realism to motivate their training. Bleda (1979) reports that trainees overall job satisfaction and job-related motivation may be improved by a well designed training program. Research is necessary to determine the dimensions of trainee acceptance of training devices just as it is necessary in the area of instructor acceptance. Before device design specifications are finalized, input concerning device acceptance should be incorporated into the process of determining those specifications.

Training Device Integration Issues. In addition to instructors and trainees accepting a training device, it is necessary for the device to be integrated into an ongoing POI. The process of integrating the training device may not always be an easy one. Often courses are designed to train groups of trainees while the training device is designed to train one trainee at a time. It may be necessary to design the training device to accommodate this team or group training approach. On the other hand, if a device proves to be more effective with one trainee at a time, it may be more beneficial to modify the existing POI to take advantage of the training device. Systematic research and coordination is necessary to determine the most efficient process for facilitating device integration.

As with other issues already discussed, the issue of device integration is an interactive one. Device design characteristics, instructor and trainee acceptance of the device, analysis of what must be trained as well as analysis of current POIs all contribute to the ultimate decisions of how to integrate the training device into an instructional context.

Noninstitutional Use of Training Devices. One of the goals of the Army Maintenance Training and Evaluation Simulation System (AMTESS) is to provide both institutional (school) training and also refresher training and skill evaluation in the field (Dybas, 1981). This is a new approach to training device utilization and basic data must be generated to determine how such device use is to proceed. Data would be useful on at least the following issues:

- differences between tasks in the institution and in the field
- types of refresher training necessary
- device acceptance
- integration of device into a field context
- evaluation of device effectiveness as field tool.

Once we have these necessary data on noninstitutional training device utilization, the Army will be in a better position to implement field operations both efficiently and effectively.

Issues in Training Effectiveness Assessment

The only remaining major section of the ISD model to be discussed is the area of training effectiveness assessment. Although we discuss this area last, in terms of an already existing POI, the assessment of training effectiveness must be the first step. The relative training effectiveness of any POI must be assessed before it may be either modified, if it is not training effective, or copied, if the program is proven to be training effective. The need for ongoing, adequate assessment cannot be overemphasized. When every training course in the military is adequately monitored, then optimal adjustments may be made to deal with any changes due to trainee characteristics, media and device utilization, training strategies, or task criteria. These adjustments may then afford the military the opportunity to maintain the training effectiveness, efficiency, and quality of its POIs at the highest possible level.

There are several possible approaches to the assessment of training effectiveness and several major issues to be considered during the selection of the appropriate assessment method(s) and types of measures. Table 5 lists

Table 5

Representative Publications which Discuss Training Effectiveness Analysis Methodology Issues

- Anderson, Ball, Murphy & Rosenthal (1973)
- ATSC (1980)
- Blaiwes, Puig & Regan (1973)
- Boldovici (1981)
- Caro (1970, 1973a, 1977)
- Evaluation of Training (1981)
- Hill & Kress (1979)
- Jeantheau (1971)
- Klein, Kane, Chinn & Jukes (1978)
- Leonard, Wheaton & Cohen (1975)
- Naval Training Device Center (1966)
- Payne (1982)

several representative publications which discuss methodological issues in training effectiveness assessment. No single approach or measure is emphasized in this report because each approach has its strengths and its weaknesses. These positive attributes as well as the problems associated with each approach must be weighed before making the decision to use any one assessment technique or mixture of techniques. The first part of this section is a review of general issues in evaluation methods and measures. In the second part of this section, different types of training effectiveness measures are reviewed, their strengths and weaknesses compared, and a few examples of each type of measure are presented. The third part of this section is a discussion of the establishment of appropriate performance standards and the measures and methods used to determine if training effectively meets these standards. The final portion of this section is a discussion of the resource requirements necessary to support the evaluation of training effectiveness.

General Training Evaluation Measurement Issues. Before an instructor, program director, or researcher can evaluate a training program, much less compare that program to a set of standards or to another program, the training effectiveness of the program must first be measured. That measurement must be relevant, accurate, and valid, or the entire procedure is a waste of time and money. There are three general issues in the basic methods of evaluation. The first issue concerns when the training effectiveness is measured. The second concerns how the training effectiveness is measured. The third issue concerns the validity of the measures that are used.

Training effectiveness measures can be divided into two general classes, process and outcome measures (Goldstein, 1974). The continual measuring of progress during training, for example, after the completion of instruction on a single task in a multitask training program, is called process measurement. The general purpose of process measures is to ensure that program goals are being met in a timely fashion and that the knowledges and skills needed for later training are being adequately learned. These measures are usually single task or single skill measures and are usually criterion-referenced, objective type measures (these terms will be explained below). Outcome measures are applied after the completion of the training program, whether the program is simple and brief or complicated and time consuming. These measures are attempts to evaluate the training effectiveness of the entire POI. They can occur immediately after training, when the trainee is first applying the new knowledge and skills on the actual job. In this case they have been called proximal measures (Goldstein, 1974). If measures are taken after some long period of time has elapsed on the job, they are called distal measures (Goldstein, 1974). The proximal measures are typically used in transfer of training (TOT) studies. Distal measures are used to evaluate long-term retention, typically with skills or knowledges that do not get used very often. Obviously, the decision to use one type of measure must be based on what kind of information is needed in the evaluation.

The choice of when to conduct the training effectiveness evaluation can introduce biases, which can influence the results of the evaluation. One example of these biases comes from research in the area of learning and retention. Atkinson (1972) used several different instructional strategies in teaching German words while investigating learning and retention. One strategy presented the paired English and equivalent German words randomly on a computer screen. Another strategy allowed the learner to select the pairs to be practiced. The third strategy was under the control of computer algorithms that were designed to present items until a criterion was reached and to optimize the number of word pairs learned to that criterion. A process measure of retention, based on the number of errors made, found that, in terms of retention, the random method was best and the computer algorithms method was worst. However, shortly after training, a proximal, outcome measure found the situation reversed. The implication is that both methods should be used whenever practical and that the results generated by the methods should be compared and evaluated before any conclusions about the effectiveness of the POI are drawn.

When determining how to evaluate training effectiveness, several issues must be considered. The first issue concerns whether the measure is based on objective criteria or whether it is based on subjective criteria. Objective criteria are quantifiable things such as rate of production, number of correct or incorrect answers, etc. A problem with objective criteria lies in the individual differences of the trainees. The previous experiences or higher aptitudes of certain trainees may mask the training effect of the POI and thus invalidate the measure. At the other end of this dimension are measures based on subjective criteria. Subjective based measures commonly use peer ratings or instructor evaluations to judge the effectiveness of the training course. The greatest problem with subjective criteria is that human estimation is very easily biased and may invalidate the measure. Care should be taken to insure that a proper mix of objective and subjective criteria are used in any program evaluation. Research on the appropriate mix of these two approaches in various evaluation applications would provide a basis for training evaluators to make informed decisions about which type(s) of criteria to use in future evaluations.

Another issue in the measurement of training effectiveness concerns how the effectiveness measures are referenced. Performance measures can be either criterion-referenced or norm-referenced (Goldstein, 1974). Criterion-referenced measures are tied to absolute standards, generally using specific objective behavioral items, although subjective items could be used. Norm-referenced measures simply evaluate the trainees' standing vis a vis their peers, a naive group, or possibly a group of experts. The best information for evaluation of training can be acquired by using objective, criterion-referenced measures. The least valuable information for evaluation of training would come from subjective ratings that are only referenced to the trainee group. All that would be known in this latter case is how the instructor thinks the trainees perform with reference to their classmates, not how they rate with reference to actually learning the required skills in the POI.

The last general issue in methods of measurement concerns validity. Ensuring that the measures used in training effectiveness evaluation are valid is probably the most difficult part of any evaluation. There are two general classes of validity, internal validity and external validity.

> Internal validity refers to the approximate validity with which we infer that a relationship between two variables is causal or that the absence of a relationship implies the absence of cause. External validity refers to the approximate validity with which we can infer that the presumed causal relationship can be generalized to and across alternate measures of the cause and effect and across different types of persons, settings, and times (Cook & Campbell, 1979, p. 37).

Internal validity is concerned with the structure of the experiment. If proper controls are not used and if proper statistical interpretations are not made, then there can be no faith that a true causal relationship exists between the variables of interest. External validity, on the other hand, is concerned with whether the experimentally demonstrated relationship can be regarded as an example of a relationship that could also be found outside of the laboratory and whether the experiment actually measured that "real world" relationship. External validity is a matter of inference. In the case of a training experiment the major focus of external validity is the generalizability of the information about the particular training situation to some other situation or to training in general. Questions about external validity center on how representative the data are of the general class of training procedures. The evaluation of internal and external validity will be one of the primary methods used to sort out and evaluate previous research on training programs for inclusion in the training research issues data base.

Types of Training Effectiveness Assessment. There are many possible approaches to the assessment of training effectiveness. All of these approaches require some use of proficiency measures, with all of the problems discussed above. Once the type of proficiency measure is selected, the next question is how to apply the proficiency information to assess the effectiveness of training. One highly acclaimed and strongly advocated approach is transfer of training (Orlansky, 1981; Orlansky & String, 1981a). In general, the transfer of training (TOT) paradigm is based on the effect a previously learned skill has on the acquisition or relearning of some second skill.

There are several different models of TOT and various derived designs, loosely based on TOT assumptions, that can be used in training effectiveness assessment (Caro, 1977). A different approach to evaluating training effectiveness is to base the overall conclusions about effectiveness on the comparative costs of different training devices (Puig, 1972; King, 1978). The common ground for both of these general approaches is that adequate measures of proficiency are required first.

As illustrated earlier in Figure 2, the assessment of training effectiveness must weigh the various external threats against the quality of instruction in an existing POI. This is usually accomplished by using proficiency tests already developed in the school. The adequacy of these proficiency tests is crucial because, short of war, there are few other methods for determining the quality of Army training and thus overall force readiness. As discussed above, there are many problems associated with the process of proficiency evaluation test development, especially in the case of training device evaluation. It may be necessary to modify existing proficiency tests in order to highlight specific questions about the design of a training device or its use in a POI. Also, based on the issues discussed above, it may be possible to modify proficiency tests in order to provide more reliable and valid data on training effectiveness. In any case, the processes involved in test development and implementation should be identified and cataloged for more systematic use and in general to maximize the efficiency of proficiency testing across the Army's MOSs.

There are three major issues which must be resolved during the selection of a method for training effectiveness assessment. The first issue to be addressed is whether to assess training effectiveness by measuring trainee proficiency or to evaluate the training device and/or POI on some other basis. For example, there are several general research designs (to be discussed below) which assess training effectiveness by using subject matter expert opinions rather than using some measure of trainee's actual performance. The second issue is whether to choose time in training or performance quality as the basic effectiveness measure. For example, a specific training device or POI may not improve the final level of performance, but may provide an adequate level of proficiency in less time. On the other hand, a training regimen or training device may require slightly more training time, but may greatly improve performance over the long run. The third issue concerns when to measure training. Is training effectiveness measured over the short term or are the measures based on long-term retention? Most training effectiveness studies are conducted in the school during or shortly after training and can provide little information about long-term trainee performance in the field. Empirical data about these three issues will facilitate management decisions about the implementation of training effectiveness assessment since decisions concerning these issues must be made before specific research designs may be implemented.

The best recent review of research designs for determining training device and training program effectiveness is by Caro (1977). A detailed breakdown of Caro's ten distinct designs is presented in Table 6. The ten approaches can be grouped into four categories: the classic TOT design and three groups of designs which differ on various dimensions from the classic TOT design. The classic TOT design will be described first and then the other three groups of designs will be discussed.

Table 6: Research Designs for Determining Training Device Effectiveness

Method	Groups/ Subjects	Pre-Test	Training	Post-Test	Comparison Method	Assumptions and/or Remarks
Transfer of Training	Exp. & Control (naive)	No	Training Device vs. Actual Equipment (AE)	Actual Equip.	Performance Differences	Optimize training via transfer increase safety, decrease cost & time. Excellent design
Self-Control Transfer	Experimental (naive)	AE	Training Device	Actual Equip.	Performance Differences	No control, no comparison to other types of training, low validity
Pre-Existing Control	Experimental Previous (naive)	No	Training Device Previous POI	Perf. Measrs.	Perf. Diffs. New vs. Old	Assumes training conditions for previous group equates to those of new group, low validity
Uncontrolled	Experimental (naive)	No	Training Device	Actual Equip.	General Evaluation	Assumed effective if after T.D. use, trainees can perform to some criterion. Poor validity
Training Dev. to Training Dev.	Experimental (naive)	No	Training Dev. (without some instruc. fea.)	Ref. Device	Performance Differences	Assumes reference device with the instructional feature is equivalent to actual equipment.
Training Dev. Performance Improvement	Experimental (naive)	Yes	Training Device	Training Device	Performance Measures	Assumes that if trainee's performance improves on the T.D. then training is effective.
Backward Transfer	(experts)	No	None	Training Device	Performance Evaluation	Assumes that if experts can perform task on T.D. then trainees can learn task on T.D., low validity
Training Dev. Fidelity	None	No	None	No	Equipment Analysis	Assumes that high similarity (fidelity) to A.E. will lead to higher transfer of training.
Training Dev. Program Analysis	None	No	None	No	POI design & Use Analysis	Assumes that if POI is well designed and implemented then training will be effective.
Opinion Survey	Operators Instructors Trainees	No	None	No	Interviews/ Questionnaires	Subjective opinion data--Of little value.

Source: Caro, 1977.

The classic transfer of training design is based on two assumptions. The first assumption is that the mastery of one skill will affect the acquisition of another similar skill. The second assumption that the best way to evaluate the effect of a training device is to compare the training outcome to a matching training program that doesn't use that training device (i.e., uses some other training device). The object of this relative evaluation is to develop the training device, or more generally the overall training program, that leads to the best performance on the actual equipment both immediately and over the long term.

As can be seen from the top line in Table 6, and as implied above, a classic TOT study involves two groups which are treated in almost exactly the same way. The control or baseline group goes through the training program without the training device of interest, using either another training device or the actual equipment for training. The experimental or comparison group goes through the same training program using the training device of interest. (Note that the same pattern would hold for evaluating <u>any</u> change made in the overall program with the intent of improving the program.) The two groups are evaluated in the same way at the end of training and their proficiency is compared in order to determine the relative training effectiveness of the new training device or training program.

The best comparative measures are to some extent based on the general TOT model. Two of the best known measures can be based on either performance levels or time in training. A percent transfer measure can be calculated to determine what increase in efficiency, expressed in percent relative to the control or baseline group, is found in the experimental or new training group (see formula 1). In this formula, T_c refers to either the time in training or to the proficiency level of the control group and T_e is the time in training or the proficiency level of the experimental group (Micheli, 1972).

$$\%\ \text{transfer} = \frac{T_c - T_e}{T_c} \times 100 \qquad (1)$$

Another measure that may be used with the TOT model is the transfer effectiveness ratio (TER). This ratio is recommended because it centers on the time or trials to some performance criterion <u>after</u> the shift to actual equipment conditions and therefore is more directly relevant to long term, on the job performance rather than just training school proficiency. In the TER formula (see formula 2), T_c refers to time or trials spent on the actual equipment by the control group, T_e is the same measure for the experimental group on the actual equipment and X_e refers to the same or a similar measure for the experimental group on the training device (Provenmire & Roscoe, 1973).

$$\text{TER} = \frac{T_c - T_e}{X_e} \qquad (2)$$

The level of performance is the same for both groups and therefore the ratio can be directly related to underlying cost variables allowing the most effective level of effort for reaching an established criterion. Use of the TER encourages delayed measures rather than immediate ones and may therefore be more indicative of long-term behavior (Atkinson, 1972). These measures are based on at least close approximations of the TOT model and are difficult to use in other types of evaluation designs.

The first group of models derived from the classic TOT design differ in the way in which they deal with the control or baseline groups. This group of models consists of: the self-control model, the pre-existing control model, and the uncontrolled model (see Table 6). The self-control model uses a pretest (a before training test on the proficiency measure) as the basis of comparison for the training program. The lack of a control group presents a problem in evaluation, since it would be a strange phenomenon indeed if no improvement was found between the first test and the second. Whether to attribute the increase in proficiency to the training device used in the training program or to some other change in the subjects becomes an insurmountable problem. The pre-existing control model, which uses pre-existing information, such as trainee scores from previous groups, may seem to alleviate this problem. However, comparisons to previous trainee groups presents other equally serious problems. The essence of the control group is that they are given the same treatment as the experimental group, with the exception of the training device experience. When comparing to previous groups, the assumed commonality may not exist. Any change in the POI, the instructors, the trainees, or the outcome measures may invalidate the comparison because performance differences, if any, may be due to factors other than the training device. Both of these types of problems, possible interfering factors and the inability to specify proficiency increases due to training, are compounded in the uncontrolled model. The major unanswered question after an evaluation based on the uncontrolled design is whether or not the level of proficiency would have been achieved without training. The assumption that because certain criteria are met the training device and training program must be effective, is completely unwarranted.

The next group of evaluation models suffers due to multiple differences from the TOT model. This group includes: the training device-to-training device model and the training device performance improvement model (see Table 6). In the training device-to-training device model, no control group is used and the assumption is that the final measure (on the new training device) is equivalent to the performance proficiency that would be found on the actual equipment. In the training device performance improvement model, the assumptions are the same as those made in the self-control transfer model, that if the trainees evidence any improvement then the training has been effective. The major problem, in addition to the lack of a control group, is that there is no real reference to the actual equipment. Both of these models attempt to measure training rather than to evaluate the training device or training program and generally use performance measures in a noncomparative fashion. Since the models do not include references to actual equipment, the measures are all immediate and the information level for predicting competence in field work is low.

The last group of models are so different from the classical TOT model that there is very little basis for comparison. This group consists of: the backward transfer model, the training device fidelity model, the training device program analysis model, and the opinion survey model (see Table 6). In the backward transfer model, an expert is tested on the training device. The assumption is that if the expert can adequately transfer skills and proficiency from actual equipment to the training device then a trainee on the device should be able to adequately transfer his or her skills to the actual equipment. While the assumption that transfer works the same way in both directions may seem reasonable, there has been no empirical verification of this assumption.

The training device fidelity model is based on the assumption that if the training device closely approximates the actual equipment then its training effectiveness must be high. The Army has sponsored the development of several predictive models, collectively known as TRAINVICE, which allow the training developer to analytically assess the effectiveness of a training device and to generate a figure of merit for each device configuration (Wheaton et al. 1976a, 1976b, 1976d; Narva, 1979a, 1979b; PM TRADE, 1979; Swezey & Evans, 1980; Swezey & Narva, unpublished). Tufano and Evans (in press) reviewed, compared, and contrasted the four TRAINVICE models. Their recommendations require research to be done in two areas: field validation of the TRAINVICE models in various task domains and longer range investigations of the model's underlying assumptions.

The training device program analysis model assumes that training will be effective if the POI is well designed and uses good instructional techniques. Both the training device program analysis model and the training device fidelity model are limited in that they only evaluate the training device or program in an analytic manner. Neither approach makes use of actual training behavior as assessed by either time-based or performance-based measures and neither provides information about the resultant transfer of skills from the training device to the actual equipment. This is also true of the opinion survey model. The data for this model consist of opinions about the POI and the training device obtained from equipment operators, course developers, instructors, and even trainees. To the extent that these "experts" are knowledgeable about training objectives and methods, their opinions may be of value. However, this process is more prone to error than a formal analysis of either the training device fidelity or the content of the POI and does not provide any substantial information about training effectiveness.

Assessing Cost Effectiveness

To reemphasize a point made by many authors (e.g., Lawrence, 1954), cost is often the ultimate criterion against which training is judged. As noted in the introduction to this section, an adequate cost effectiveness appraisal must be based on an adequate training effectiveness assessment. The position taken in this paper is that the efficient and correct use of the ISD process requires the use of an adequate empirical assessment of training effectiveness that can lead directly to reasonable cost analyses.

One popular method of cost analysis, that is not always based on the use of adequate assessments of training effectiveness, is a simple one-to-one cost comparison of training devices and/or actual equipment trainers (Puig, 1972; King, 1978). Puig (1972) compared two groups trained on either actual equipment or a training device. The basis of the comparison was the amount of time each group spent using their respective training equipment when both groups achieved approximately the same level of proficiency on a transfer task. The actual equipment cost $6.00 per hour while the training device cost only $2.00 per hour, so Puig's recommendation was to use the training device in the POI. King (1978) approaches the same comparison by emphasizing the total front end cost of the training device and the actual equipment. Both of these comparisons are narrow in that they do not actually center on training effectiveness improvements, flexibility in the training device, safety, or other factors that can and perhaps should be included in the assessment.

Another general method of cost analysis is firmly based in the transfer effectiveness ratio (TER) discussed above. As Provenmire and Roscoe (1973) pointed out, the selection of training devices must be based on cost effectiveness, which in turn is based on a comparison of training effectiveness. The TER allows a direct comparison in terms of time trial costs. The TER demonstrates how much can be saved by using a less costly training device for some training trials rather than using more costly actual equipment trainers for all of training. This method allows training device assessments to support actual cost tradeoffs while maintaining an adequate level of proficiency assessment (Holman, 1979; Bickley, 1980). In addition, the use of incremental transfer effectiveness ratios (Roscoe, 1971; Roscoe, 1972) based on varying amounts of training device and comparison device utilization allows determination of the most effective trade-off point for transfer to the actual equipment (Provenmire & Roscoe, 1973; Bickley, 1980). This method therefore affords the opportunity to minimize cost while maximizing transfer (Fink & Shriver, 1978).

Some authors (Lawrence, 1954; Micheli, 1972) argue that cost effectiveness can and should be extended beyond the simple comparison of equipment costs to other, perhaps more important areas. Micheli (1972) argues that the possibility of variability in training, the training control differences, and safety factors that the training device may afford should be entered into the overall cost analysis. Lawrence (1954) argues that the total cost of training should be the major determinant for overall training program evaluation. The measurements and cost comparisons should also be based on supervisory costs, on-the-job training costs over the entire maintenance career, equipment and personnel damage and attendant costs, etc. in order to analyze the complete system and all its integral parts. Allbee and Semple (1981) developed a hierarchical cost model which relates training costs to the cost interests of various levels of Air Force management. They recommend that their basic model be expanded to include more subjective parameters such as flight safety and force readiness. Knerr and Matlick (1980) reviewed several methods for applying cost and training effectiveness analyses at various points in the Army's Life Cycle System Management Model (LCSMM). A computerized cost effectiveness model was developed by Marcus et al. (1980). Further research to validate and improve the applicability of these models is needed. In addition, an effort to synthesize the best aspects of each model and create a generalized cost effectiveness analysis methodology would greatly simplify the process and facilitate its use in the Army and the other services. A comprehensive cost effectiveness analysis methodology will afford the opportunity for decision makers to make tradeoffs between the costs of training devices and their training effectiveness.

Most training effectiveness studies are conducted in the school shortly following training. These studies tell us little or nothing about how well the trainee does in the field, both immediately and over the entire career. In addition, there are very few adequate cost effectiveness surveys performed to ensure that both short-term and long-term cost/proficiency tradeoffs are being balanced. Research and formalized follow-up testing could do much to provide these data. A system of follow-up testing procedures would require close coordination between TRADOC and FORSCOM. At this time it would seem appropriate to conduct a feasibility study on the development of such coordination.

Resource Requirements. An incredible amount of material and personnel resources are necessary to conduct research on all of the issues described above. The problem is that no single Army agency possesses all of these resources. Additionally, expertise is required in many areas from test design and data interpretation to weapon operations and maintenance procedures. Furthermore, it is essential that the ISD process make the best use of subject matter experts from all fields. One approach to dealing with resource problems would consist of an analytical study pinpointing the required resources, both in terms of technical expertise and logistical support, at each point in the ISD process. This effort would be a first step in the establishment of resources and coordination of efforts for performing research into all of the issues raised in this article. Another approach, perhaps more realistic in terms of scope and resource utilization, would be to organize existing data and apply the ISD process to a particular training program in order to identify and prioritize research issues for that program. This effort would serve as a trial run for the procedures that would eventually be required for Army-wide training programs. Such a smaller scale effort could help in determining the feasibility of an Army-wide effort and would be within the resource constraints of a single Army agency.

SUMMARY AND RECOMMENDATIONS

In this paper we have argued that a training device research issues data base and training device design guidance system should be a primary goal in the Army training community. It is our belief that informed decisions on the design and implementation of training devices and training programs must be based on the best available empirically derived information on the training effects of various training system variables. In order to provide the conceptual organization for this training system research issues data base, we have accumulated some of the existing data and organized the information around important development and research questions. Our approach emphasizes the use of existing data for short term guidance but the iterative development of improved guidance as new data are developed. A well organized data base will facilitate both of these goals and an automated expert system can help insure that training system design guidance is delivered to users in a form that will be of immediate value.

In the first section of the paper, a tentative plan for the accumulation and distribution of the data derived from the study of training system research issues was presented. This plan recommends the establishment of an iterative data base, which would be updated as newer, more valid and reliable data are developed. This data base is proposed as the foundation for user-oriented training system design guidance. Such guidance would be organized around user-generated questions and would translate raw data into guidance statements which would be of direct value to training system designers. This guidance could take the initial form of a guidebook but the authors feel that automation in an expert system format would be more advantageous over the long run.

The second section is a presentation of the basic instructional system design (ISD) progression in terms of the major areas and relationships in the cycle. The emphasis is that no single research issue connected to a single stage in the ISD process stands alone. The systemic nature of the ISD process forces training program developers, administrators, and researchers to view training system issues as completely interactive and interdependent. It is the authors' opinion that very little progress can be made in the investigation of training system and training device issues if one maintains an isolationist view of these issues.

In the third major section of the paper, we presented some of the elaborations of the main ISD research issues which we feel must be studied if instructional programs are to be designed for maximum efficiency and effectiveness. Each research issue was discussed not only as it relates to training device design, but also as it interacts with other issues and other aspects of ISD. Existing data from previous research were also reviewed in this section. Table 7 provides a summary of all the research questions discussed in this section.

The authors have not attempted, in this paper, to assign priorities to the research issues. ARI has, however, several ongoing efforts in the area of training device fidelity which will provide the first entries into the data base. One experiment (Baum, Riedel & Hays, in press) investigated the effects of simulator fidelity in a mechanical maintenance task. This experiment is currently being replicated at ARI. An additional series of experiments is ongoing at the George Mason University, Fairfax, Virginia (Allen & Hays, 1983). In this series of experiments the effects of simulator fidelity are being investigated in the context of an electro-mechanical troubleshooting task. Several interactive variables, such as trainee aptitude, task difficulty and instructional strategy will also be investigated in this effort. A third effort will produce an annotated bibliography of over 150 training device effectiveness articles. The bibliography is being formatted for direct entry into the data base. As soon as these first entries are incorporated into a prototype data base the data themselves can be used to help researchers assign priorities to the issues discussed in this paper.

Table 7

Summary of Training System Issues Requiring Empirical Investigation

Area of Interest	Research Questions
I. Training Needs Assessment	
A. Task Analysis	1. How are task analyses currently conducted in the Army and the other services?
	2. Can a standardized task analysis format and methodology be developed? What are its characteristics?
	3. Can a workable taxonomy of tasks be developed? What are its characteristics?
B. Media Selection	1. How are media selection models currently used in the Army and the other services?
	2. Which, if any, existing media selection models are valid? What modifications are required to increase their validity?
	3. Can a media selection model be developed which includes specifications for the characteristics of the instructional medium selected?
	4. What are the training effects of various media mixes?
	5. What is the appropriate instructional medium for use at each stage of training?
	6. How does the interaction of media and media mixes with other training system variables affect training?
C. Trainee Characteristics	1. What are the appropriate training device characteristics and training strategies for each type of trainee?
	2. What are the enabling skills required for each type of training device?
	3. How can trainee motivation be manipulated to improve training?
	4. What are the effects of learning set on training?
	5. Are there neurological differences among trainees that affect training outcomes? How can training effectiveness be improved by taking these neurological differences into account?

Table 7 (continued)

Area of Interest	Research Questions
D. Training Strategies	1. When is a general rather than a specific training strategy appropriate? 2. When should generic rather than specific tasks be trained? 3. When is part-task rather than whole-task training more appropriate? 4. When is it more training effective to use lock-step rather than self-paced training? Can a mix of the two types be training effective? 5. When is it more training effective to use trial and error learning rather than error free learning? 6. How are current learning guidelines used? Are current guidelines valid and user-oriented? How might their use be improved?
II. Training Device Design	
A. Training Device Fidelity	1. What are the relative training effects of various levels of physical and functional fidelity? 2. How do the two aspects of fidelity interact with other training system variables?
B. Instructional Features	1. What are the training effects of each specific instructional feature that can be included in a training device? 2. When should training feedback be augmented and by what means? 3. When and how should fading be used in training?
C. Training Device Architecture	1. When is it more training effective to use 2D rather than 3D for hands-on practice? 2. What is the best mix of student and instructor stations for training specific tasks with different training devices and training strategies? 3. When are each of the different types of trainee-device interaction most training effective?

Table 7 (continued)

Area of Interest	Research Questions
III. Training Device Implementation	
A. User Acceptance	1. What are the factors that make a training device acceptable to instructors? to students?
	2. What are the effects of nonacceptance of training devices?
B. Training Device Integration	1. How can training devices be most easily integrated into POIs?
	2. What are the training effects of poor device-POI integration?
C. Noninstitutional Use of Training Devices	1. What are the candidate noninstitutional uses for training devices?
	2. How do specific tasks change when in a noninstitutional context?
	3. What are the special problems with device acceptance and device integration in a noninstitutional context?
	4. When and what types of refresher training could be delivered with noninstitutional training devices?
	5. How would devices be evaluated in a noninstitutional context?
IV. Training Effectiveness Assessment	
A. Evaluation Measurement	1. What are the relative values of process and outcome measures? When is the use of one rather than the other more appropriate?
	2. What are the relative values of proximal and distal measures? When is the use of one rather than the other more appropriate?
	3. What is the appropriate mix of objective and subjective criteria in training effectiveness evaluation?
	4. What are the relative values of criterion and norm-referenced performance standards? When should one be used rather than the other?
	5. What is the best mix of the above types of measures for specific contexts?
	6. How can training effectiveness measures be made more valid?

Table 7 (continued)

Area of Interest	Research Questions
B. Types of Training Effectiveness Assessment	1. How does the Army develop and use proficiency tests? 2. Which types of proficiency measures provide the best inputs for training effectiveness evaluation?
IV. Training Effectiveness Assessment (continued) B. Types of Training Effectiveness Assessment (continued)	3. How do the data from other training effectiveness measures correlate with transfer of training data? 4. How can cost effectiveness and training effectiveness data be best used to evaluate training? What is the validity of existing cost effectiveness assessment models? How can their application be enhanced? 5. What is the validity of existing analytic models for assessing training effectiveness? How might such models be improved? 6. How can coordination be established so long-term retention data can be used to evaluate training effectiveness?
C. Resource Requirements	1. What are the required resources to adequately assess training effectiveness? 2. From which agencies within the Army and the other services can the necessary resources to assess training effectiveness be obtained? 3. How can the required coordination between the above agencies be facilitated?

If training programs are to keep pace with rapidly evolving technologies and provide the most cost effective training possible, their design and implementation can no longer rely on merely intuitive approaches. It behooves instructional system designers to use the best available empirical data to aid in the design of training devices and training systems. An expert system that is grounded in empirical data on each and every research question discussed in this paper would be an invaluable aid to the training community. The use of such an expert system would improve both the cost and the training effectiveness of instructional delivery systems.

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Appendix A: Types of Task Analyses

There have been numerous approaches to the analysis of tasks. Several researchers have attempted to classify these approaches. One of the most widely used classifications of types of task analyses divides them into four conceptual bases (Wheaton, 1968; Fleishman, 1975; Fleishman, 1977):

1. The Behavior Description Approach
2. The Behavior Requirements Approaches
3. The Abilities Requirements Approach
4. The Task Characteristics Approach

The (1) behavior description approach (McCormick, Jeanneret & Mecham, 1972) is based upon observations and descriptions of what people actually do while performing a task. It provides an observer's view of the actions of a task performer. An example of a behavior description might be "pulls lever until pressure warning light goes out." The (2) behavior requirements approach (Gagne, 1962; R. Miller, 1962; Annette & Duncan, 1967), emphasizes the cataloging of behaviors which are assumed to be required in order to achieve criterion levels of performance. This approach would, for example, detail how quickly, with how much force, and for what duration the above lever would have to be pulled in order to adjust the pressure to its desired level. The (3) abilities requirements approach (Fleishman 1977; Theologus & Fleishman, 1971), describes, contrasts, and compares tasks in terms of the abilities that are conceived as being relatively enduring attributes of the individual performing the task. The assumption is that different tasks require different abilities. In our lever pulling example, this approach would focus on the motor skills and the perceptual requirements necessary for individuals to accomplish the lever adjustment. Finally, in the (4) task characteristics approach (Fleishman, 1972; Farina & Wheaton, 1971; Hackman, 1970), task description is predicated upon a definition that treats the task as a set of conditions which elicit performance. The assumption is that tasks may be described and differentiated in terms of intrinsic objective properties which they may possess. The components of a task (an explicit goal, procedures, input stimuli, responses and stimulus-response relationships) are treated as categories within which to devise task characteristics or descriptions.

Besides the four discussed above, two additional conceptual bases have been described.

5. The Phenomenological Approach
6. The Information-Theoretic Approach

The (5) phenomenological approach (Klein, 1977) focuses on the way the task is experienced. It seeks to provide a holistic understanding of the system in which the task is embedded. In the (6) information-theoretic approach (Levine & Teichner, 1971), the task is conceived as a transfer of information between components of the system (man-machine, machine-man, man-man, or machine-machine).

Tasks are categorized based upon the constraints on information flow between components.

These six approaches to task analysis are alternative ways of viewing the process of task analysis. Each has a different goal and produces a different form of output. The distinctions between the approaches are important because by choosing one approach over the others, we are likely to obtain different results. These various results are due to the different criteria each approach applies to the analysis of the task. In 1969 Farina made a statement which is probably still true today. He stated that there are no deliberate eclectics in the field of behavior description. Each researcher seems to have his/her own purpose and chooses the approach which fits the purpose most closely. Farina also makes the important point that performance is a function of the task, the characteristics of the operator, and the characteristics of the environment ($P = f(T,O,E)$). While behavioral descriptors focus on the O portion of the equation, it is also necessary to obtain descriptors for the T and E portions. Table A lists these six approaches and indicates to which portion of the above equation they most closely apply. As can be seen from Table A, each type of task analysis, while not necessarily ignoring all other areas, does have a central area of concern.

Table A

Six Approaches to Task Analysis
and Their Main Areas of Concern

Approach	Main Area of Concern
1. Behavior Description Approach	Operator
2. Behavior Requirements Approach	Task
3. Abilities Requirements Approach	Operator
4. Task Characteristics Approach	Task
5. Phenomenological Approach	Operator
6. Information-Theoretic Approach	Task/Environment