

LOCK-STEP VS. FREE-PLAY MAINTENANCE TRAINING DEVICES-
DEFINITIONS AND ISSUES

Dee H. Andrews

Human Factors Division
Naval Training Systems Center
Orlando, FL

and

Hans W. Windmueller

Maintenance Trainers Branch
Naval Training Systems Center
Orlando, FL

ABSTRACT

Increasing computer capability together with greater understanding of the learning process have resulted in improvements in the instructional capability of training devices. This complexity has spawned a great diversity in training device design approaches. Nowhere is this diversity more apparent (and often less understood), than in the design of maintenance trainers. The military is currently procuring both lock-step and free-play maintenance trainers at significant cost. Lock-step trainers lead the trainee through prescribed maintenance training in a pre-determined, pre-programmed fashion. Free-play trainers have no prescribed maintenance path. Trainees, therefore, are free to perform any set of procedures in any sequence. The device simulates real equipment in every way possible and will not automatically freeze when a mistake is made. Unfortunately, the purposes of the two device types are often confused. Decreased training effectiveness and increased cost are commonly the result.

This paper examines differences between lock-step and free-play maintenance trainers and explores appropriate uses of each. Major issues which should be considered when determining how much free-play and/or lock-step to design into a training device are discussed in the paper. These issues include the expertise of the trainee; complexity of the tasks to be learned; the number and skill levels of the instructors; the nature of the actual operational equipment; and the cost of procurement.

Introduction

The military's use of training devices is continuing to grow at a rapid pace. For example, the Navy's inventory of simulated training devices is currently well over \$1.2 billion dollars, and that figure is expected to grow at a rate of 15 percent a year (Nauta, 1984)². While critics have been able to accept the general concept of simulators as components of effective training systems, they continue to question the way in which training devices are used.

"We found that the services are not always analyzing their training needs and thus do not know what tasks can best be taught on simulators As a result, the simulators are not being used as effectively as they could be." (p. 1, GAO, 1983)¹.

The problems of proper training device design and use apply not just to operator training devices, but also, to an array of maintenance devices.

Confusion over the type of maintenance training devices increases the risk that ineffective devices may be built. This discussion is based upon the experience of the writers in designing maintenance training systems, primarily Device 11G2 (Close-in Weapon System Maintenance Trainer) and Device 11G3 (MK92 Fire Control System Maintenance Trainer). We could find no empirical research in this area and so the readers are invited to interpret the opinions and conclusions in light of their own experience.

It is important to realize that we view the two types of trainers not as mutually exclusive concepts but rather as end points on a continuum. Training systems may end up having a design which combines both device types. In most cases the issue is not whether a maintenance training system will be either lock-step or free-play, but rather where on the continuum, the final training device design will fall. For example, Windmueller (1984)⁴ describes a system which allows both lock-step and free-play training to be done using the same trainer. Another approach might use a large, free-play trainer for most of a training system and small, part-task, lock-step trainers for some selected aspects of the system. Ineffective designs occur because designers ignore the existence and characteristics of this continuum.

A final note. Generally, a training device, be it lock-step or free-play, is no more effective than the training system of which it is part. In like manner, a training system is only as effective as the training strategy which it implements. While we recognize the vital importance of the concepts of lock-step and free-play training strategies and systems, we have limited our discussion here to training devices.

Lock-Step and Free-Play Training Devices Defined

The lock-step device is defined as that which leads a trainee through each portion of each exercise with very little, if any, deviation from the prescribed program of instruction. The intention of a lock-step trainer is to teach hard and fast procedures in the most efficient manner possible. Usually, only those portions and functions of the actual equipment

which must be simulated for sake of the training objectives are programmed into a lock-step trainer. If the analyst is able to specify exactly which skills must be taught and then develop objectives for them, it would be inefficient to build a device which includes more equipment and functions than is required. A lock-step device's programming is done in serial order. With this method of simulation, the computer's real-time programming capacity and execution speed become relatively unimportant. The storage medium may involve a large capacity, but high retrieval speeds are usually not required.

The free-play training device allows trainees to define and pursue their own course of maintenance training within the limits of the curriculum. The device is designed to replicate the actual equipment as closely as possible, in function and often in form. A general difference between the two types of training devices centers on the freedom of the trainees to explore different approaches to analyzing and remedying maintenance problems.

In the free-play device, programming is used to model the actual performance of the equipment for which training is designed. This programming then allows the students to either follow a pre-set procedure or take alternative paths in order to experience the same effects of correct and incorrect actions as they would in the real-world environment. With this method of simulation, the program, which simulates the full range of the real equipment cues, is resident in the computer's memory, so the device emulates accurately a real-world environment allowing student free-play. A free-play device requires a relatively large, high speed computer.

There is far less technical risk involved in fabricating a lock-step maintenance trainer in comparison to its free-play counterpart. In the lock-step design, each step or action the student will, and must, take is well defined allowing a very accurate estimation of programming labor. Conversely, in the free-play simulator the student can take many paths to a maintenance solution which requires complete and precise system modelling to the required level of fault isolation to be trained. A lock-step trainer can be designed around a "limited" model of the prime equipment. If so, changes to software can be made parametrically as in the free-play trainer. Accurate, detailed modelling demands a thorough knowledge of the equipment to be simulated. This requires access to the actual equipment and detailed design and performance data.

In comparing the use of these methods of maintenance trainer simulation, it becomes apparent that the lock-step trainer is actually a procedures trainer which imposes serial actions on the student in order to function. It cannot function in a free-play mode. The free-play trainer is a simulation of the actual equipment and as such responds to student actions, both correct and incorrect, as would be experienced on the job. Additionally, the free-play trainer can be employed in a lock-step mode by overlaying the simulator programming to limit the student to a single path to a solution. This overlay technique could be further modified to allow the student to take any pre-

designated number of incorrect steps before the program halts the student's interaction. In short, a free-play trainer can be used as a lock-step trainer, but the opposite is not true.

Cost Comparison of Lock-Step and Free-Play Devices

The lock-step trainer is generally less costly to acquire, initially, than the free-play simulator, assuming comparable task and equipment complexity. Generally, our experience indicates that the one-time cost of software programming labor will be many times greater for the free-play simulator than the comparable lock-step trainer. There is some controversy about the relative cost of hardware with each trainer type, but since the cost of hardware in most modern trainers is a relatively small amount, when compared to software cost, we will not discuss the topic in detail.

Certain life-cycle factors can actually alter the overall costs in such a manner as to make the free-play less expensive in the long run. Further, should modifications be required to maintain the trainer in compatible configurations to the actual equipment simulated, the modifications will be substantially simpler to accomplish on the system software. It is possible to simply change the simulator software at the same point in the model as the equipment simulated change occurred. Conversely, for lock-step, there is no relationship between the actual equipment change and changes in the trainer. Actual equipment changes can cause substantial unanticipated problems and attendant expense in modifying the trainer. Free-play changes are usually parametric. Lock-step changes may have to be made numerous times throughout the program.

With these generalities in mind, one can see that a crossover cost for free-play versus lock-step may occur. Initial cost is higher for free-play, but significant actual equipment changes can bring free-play's total life-cycle cost below that of lock-step. The exact crossover quantity will, of course, vary with the hardware to software ratio and the actual complexities of the operational equipment to be trained.

Confusion Factors

At least two factors lead to the decision to use one device type exclusively, when the other device type or a mix is more appropriate. The first major factor is related to analysis and design issues. Various systems approaches used for analysis and design (e.g., the military's Instructional Systems Development model) may be misused in developing maintenance trainers. The second factor relates either to the designer's misunderstanding about differences between maintenance training devices or to an inability to make use of the knowledge.

Analysis Problems. The task analyses used to define the training system design sometimes lack the quantity or quality of information required. Lack of time, resources, analysis expertise, or a combination of these produce task analyses which fail to define the kind or number of tasks which are performed on the actual equipment. This lack of specificity

hampers efforts to select the key tasks which need to be trained and must be designed into the training system. When the training task selection process produces an incomplete or inaccurate list of critical tasks, this in turn makes media selection a difficult and error prone process. It is at the media selection step of the system design process that key decision errors can occur concerning the type of maintenance trainer to build. Reynolds, Dwyer, and Rizzo (1983)³, present an excellent description of steps and procedures required for the proper identification of maintenance training device functional requirements.

Inappropriate Selection Problems. An instructional strategy (i.e., lock-step approach vs. free-play) and the delivery vehicle that will be used to present that strategy and its attendant instruction to the trainee (e.g., CAI, 2-D flat panel, 3-D, actual equipment) are related but separate entities. Designers can become so concerned with decisions about the delivery vehicle (e.g., flat panels, actual equipment, CAI, 3-D) that they forget to consider key issues about the instructional strategy most appropriate for maintenance training. This danger is compounded when the task analysis data is deficient in some way.

Past experience has shown that even when designers understand the differences between the trainer types, they may have difficulty in making the right choice. User bias creates pressure to build a certain kind of trainer, and this may override rational decisions. The school for which the trainer is intended may have always used one type of trainer, regardless of the training requirements. The school personnel may not allow another kind of trainer to be used. The contractor who fabricates the trainer may be able to write a proposal which corresponds to one maintenance trainer design but lacks the technical expertise to actually produce that device. Despite the designers' best efforts, the trainer ends up functioning in an ineffective manner.

Because of the higher initial cost of procuring free-play trainers, some designers, under pressure from sponsors, may shy away from specifying that approach. Cost is certainly a serious consideration and may, at times, prohibit use of the proper trainer design. However, even if this decision is forced upon the users, the designer should make every effort to explain why the decision is necessary, what sacrifices are being made, and what can be done (if anything) to overcome the situation.

The negative results of incorrect training device choice have given justification to the critics of maintenance simulation. These critics include some instructors, some hardware manufacturers, and various governmental evaluative groups (e.g., GAO). While it is not possible to deny all the criticism of past trainers, it is possible to improve training system design in the future. It is to that end that the suggestions in this paper, and especially those in the next section, are aimed.

Decision-Making Issues for Maintenance Training Device Selection

Based upon our experience, we have developed a list of key issues/criteria for training device selection. Our first notion was to build a classical decision tree algorithm. However, we soon found that the key elements of the decision process were disparate enough to prevent an effective use of the normal binary decision points of a true algorithm. We then attempted to construct a five point rating scale for each decision criterion. This also proved to be difficult since a clearly definitive lock-step/free-play decision is not constant for each criterion. For example, it is usually the case that if the schedule for the course is extremely tight, a lock-step training system would be the best choice because of its normally efficient use of time. However, that is not always true. It depends greatly upon the previous background of both the students and instructors. This same problem of non-constancy plagued virtually all the decision criteria that were identified. As mentioned previously, there is very little research in this area to guide the developers and users of such a rating scale and so we abandoned the idea.

What we are left with are the twelve criteria for selection. We do not feel comfortable in doing anything more than merely listing and discussing them. We do feel, however, that each criterion should be carefully considered by analysts and training system designers when a maintenance training device is developed. In addition, it is strongly urged that the research community continue to examine these criteria and others so that eventually, a prescriptive tool can be developed with some confidence to aid system designers.

The criteria are listed below, along with the range of possible variables for each criterion which a designer is likely to find in a training situation. Remember that a training device continuum is advocated here. So, even though full lock-step or free-play approaches are discussed below, most training situations will call for some combination of the two approaches.

A final note - For each criterion we provide what we feel would be a "usual prescription." That is, in most circumstances, we feel certain responses would lead the designer to choose particular device designs. However, these prescriptions are not cast in concrete, and the analyst may find reasons for choosing a device which is diametrically opposed to the "usual prescription." In short, use your best judgement.

Decision Criteria

1. Training tasks and procedures - Training tasks can range from very well defined to virtually undefined.

Usual prescription - Tasks that are well defined allow detailed objectives to be developed and so lend themselves to a lock-step approach. Tasks that are undefined at the time of design require much flexibility for later system definition and so a free-play approach is advised.

2. Training objectives - objectives can range from very well defined to virtually undefined.

Usual prescription - The rationale for prescription is much the same as that given for training tasks discussed above. Well defined objectives, with detailed condition and standard statements, can best be accomplished with a lock-step device. Virtually undefined objectives require greater strategy flexibility and thus can be accommodated by free-play.

3. Trainee background in maintenance pre-requisites - Background can range from no background to deep background.

Usual prescription - No background means the trainee must be led through every objective and so lock-step is prescribed. Deep background means the trainee is better able to learn in a less controlled environment and so free-play is warranted.

4. Trainee exposure to actual equipment while on the job - Exposure can range from no exposure to considerable exposure.

Usual prescription - No exposure means that the trainees need detailed guidance (lock-step). Deep background indicates a set of advanced trainees who basically can develop and follow their own maintenance strategies in learning (free-play).

5. Time allowed for the training course - Time ranges from extremely tight schedule to virtually no limits on time available.

Usual prescription - Extremely tight schedules mean it is necessary to choose the most time efficient device (lock-step). Broadly defined time limits allow trainee exploration of new maintenance strategies which lead to the free-play approach.

6. Maintenance strategy for the actual equipment - Maintenance strategy can range from very well defined to virtually undefined.

Usual prescription - When the maintenance strategy is well defined, the processes of maintenance can be clearly identified, and detailed objectives can be developed (lock-step). Undefined strategies require much greater training system flexibility and so the free-play approach is desired.

7. Documentation for the operational system - Documentation can range from complete, well written, detailed instructions which require no interpretation on the part of the technician to incomplete, poorly written instructions which require great interpretation.

Usual prescription - Documentation which requires no interpretation fits nicely into the lock-step mode. Free-play training systems allow much trainee interpretation.

8. State of the actual equipment - Actual equipment can range from non-dynamic with no future equipment changes projected to dynamic, rapidly changing, with future changes likely.

Usual prescription - Since the cost of modifying a lock-step training device is significantly higher than it is for a free-play device, the designer would opt for the lock-step approach only when the actual equipment is in a static state.

9. Amount of proceduralization of job - Proceduralization can range from highly proceduralized to non-proceduralized, highly fluid.

Usual Prescription - Highly proceduralized jobs usually have clearly stated training tasks and objectives and lend themselves well to efficient lock-step devices. A lack of proceduralization typically calls for training system flexibility to accommodate more ambiguous instructional requirements (free-play).

10. Number of instructors - Instructors range from shortage of instructors to excess of instructors compared to requirement.

Usual prescription - Instructor shortages mean that trainees will receive less individual attention. Therefore, more instructional automation is required. A lock-step device will allow more automatic instructional aids to be used since the training paths are more clearly defined in a lock-step approach. When it is possible to have a relatively low instructor/student ratio, less automation is required and so, a free-play device, with its opportunities for more interaction with dynamic cues, is perhaps more useful.

11. Instructional skill/background of instructors - This criterion can range from no background, skill level expected to be low to all instructors have teaching experience and training in instruction.

Usual prescription - When the instructors are inexperienced and have few instructional skills, it is usually better to design the training system so that each training phase is as efficiently constructed as possible. This tight definition places less requirements on the instructors to develop novel, yet effective, training approaches as new problems arise in the course (lockstep). Highly skilled instructors are better able to cope with the ambiguities and new discoveries which a free-play device is likely to produce.

12. Need for trainee performance measurement - Need ranges from great to no need.

Usual prescription - It is more difficult to build performance measurement capabilities into a free-play device than into a lock-step device. Therefore, if the analyst determines that a great need exists for trainee performance measurement, it will probably be advantageous to select the lock-step strategy. If no need exists, the designers would feel more comfortable in specifying the free-play approach.

It is possible that the experienced reader will be able to identify more criteria than have been specified above. In addition, different types of prescription rationales may be identified. The analyst should carefully weigh the situational specifics of each decision criterion before designing the training system. We feel that more thought, discussion and research are required for all of these design decision issues and welcome an ongoing dialogue on these topics.

Conclusions

The necessity to accurately determine how best to present training in the maintenance area is crucial. Declining skill levels of trainees will mean that the training community will no longer be able to present instructional materials and devices which are not as effective and efficient as possible. Maintenance technicians, with appropriate skill levels, are needed in the field and fleet as quickly as they can be placed.

As the training community attempts to counter its critics, it is vital that the proper training devices be designed and developed. We believe that the issues raised in this paper must be satisfactorily addressed before maintenance training can truly reach its full potential. The training device issues discussed in this paper should cause training analysts and engineers to think about the most useful means of attaining appropriate maintenance training. Many research questions need to be examined in relation to these device issues. However, the training community cannot wait for all of the questions to be answered before training devices are designed. Decisions are being made daily about maintenance training, and this paper has hopefully set forth some key topics which should be considered in maintenance training device design.

References

1. GAO/FPCD-83-4 Greater Benefits to be Gained from DoD Flight Simulators, 1983.
2. Nauta, F. Alleviating Fleet Maintenance Problems Through Maintenance Training and Aiding Research: NAVTREQUIPCEN technical report MDA903-81-C-0166-1, Orlando, FL, 1984.
3. Reynolds, R.E., Dwyer, D.J., and Rizzo, W.A. General Specification for Procurement of Maintenance Training Simulator Functional Requirements: NAVTRA EQUIPCEN Specification N-712-357, Orlando, FL, 1983.
4. Windmueller, H. Maintenance Training: The Free-Play Approach. Proceedings of the Sixth Interservice-Industry Training Equipment Conference, Washington, DC, November 1984.

ABOUT THE AUTHORS

Dr. Dee H. Andrews is a psychologist in the Human Factors Division of the Naval Training Systems Center. His work at the Center has included Instructional Systems Development, transfer of training analyses, training device evaluation, maintenance trainer design and Instructor/Operator Station research. He received a Ph.D. degree in Instructional Systems from Florida State University.

Mr. Hans Windmueller is an Acquisition Director with the Naval Training Systems Center. He is currently assigned to the Maintenance Trainers Branch and is responsible for the acquisition of complex maintenance trainers in Naval Sea Systems and Naval Air Systems Command areas. He completed his undergraduate work in electrical engineering at the Virginia Polytechnic Institute. Prior to joining the government, he was employed in various engineering and technical management positions at Melpar, Inc., on the MSQ-1A Radar Guidance System and F-100 Flight Simulator. Subsequently, he worked at ACF Electronics in engineering and technical management positions related to aviation ASW flight and weapon system trainers. Since coming to the Center, Mr. Windmueller has served at a senior engineering level in modifications and acquisitions of various operational flight and weapon system trainers and in the physiological trainer and life support areas.