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AUTHOR	Hansen, Duncan N.; And Others
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ABSTRACT

Computer simulations of three individualized adaptive instructional models (AIM) were undertaken to determine if these models function as prescribed in Air Force technical training programs. In addition, the project sought to develop a user's guide for effective understanding of adaptive models during field implementation. Successful simulations of the Drill and Practice Model, the Pacing Model and the Monitoring Model were accomplished and operational feasibility was demonstrated. In addition, a User's Guide was prepared and a single integrated technical package developed to describe how the models operate. It was recommended that simulations of at least two additional models--Concept Acquisition and Dynamic Programing--be made and that empirical validation of model effectiveness be conducted employing actual students in real time. Such research would allow the comparison of alternative instructional strategies, assess student attitudes toward computerized instruction, and provide a means of gaining experience in the optimization of instructional strategies prior to widespread Air Force implementation. (Author/PB)

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A GUIDE TO COMPUTER SIMULATIONS OF THREE ADAPTIVE INSTRUCTIONAL MODELS FOR THE ADVANCED INSTRUCTIONAL SYSTEM PHASES II AND III

By

Duncan N. Hansen
Robert Tennyson
H. Dewey Kribs
Susan Taylor
Tom James
Peter Tam
Center for Computer Assisted Instruction
Florida State University
Tallahassee, Florida 32306

TECHNICAL TRAINING DIVISION
Lowry Air Force Base, Colorado 80230

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AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235

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This report has been reviewed and is approved.

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This report concludes Phases II and III of Air Force research on the application of Adaptive Instructional Models (AIM) to Individualized Technical Training. Phase I research concluded with a recommendation to employ five state-of-the-art AIMs in the Air Force Human Resources Laboratory's Advanced Instructional System (AIS). Adaptive models recommended for AIS field implementation included (1) Drill and Practice, (2) Concept Acquisition, (3) Complex Tutorial, (4) Algorithmic Regression, and (5) Dynamic Programming. Two additional models were analyzed and recommended for further research prior to field implementation within the AIS. These models were (1) Natural Language Processing and (2) Automaton Models. Findings related to the simulation of three adaptive models and a user's guide for the models simulated are provided in the present report. Additionally, the report includes applied recommendations and methods for model validation.

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SUMMARY

Problem

Providing cost-effective training by maximizing student proficiency, while simultaneously minimizing student completion time and training costs is predicated upon effective instructional strategies. Analyses of past instructional strategy research indicated a current need for refining and developing quantitative instructional strategy models capable of adapting instruction to widespread differences among students. The question was, "Which adaptive instructional models are suitable for cost-effective technical training?"

Subsequent to careful analyses and reviews of numerious adaptive instructional strategy models, Phase I research concluded with a recommendation to implement five Adaptive Instructional Models (AIM) within the Air Force Human Resources Laboratory's Advanced Instructional System (AIS). Adaptive models recommended for AIS field implementation included: (1) Drill and Practice, (2) Concept Acquisition, (3) Complex Tutorial, (4) Algorithmic Regression, and (5) Dynamic Programming. Two additional models were analyzed and recommended for further research prior to field implementation within the AIS. These models were (1) Natural Language Processing and (2) Automaton Models.

To minimize adaptive model operational problems, prior to field implementation within the Advanced Instructional System (AIS), it was deemed important to test the operational feasibility of the selected adaptive models. One method was to computer simulate adaptive model operations to determine if they function as prescribed. Hence, three adaptive instructional models were selected for computer simulations.

Objectives of the combined Phase II-III research tasks were to: (1) provide computer simulations of three previously developed adaptive instructional models, (2) demonstrate adaptive model operational feasibility for use in the Advanced Instructional System (AIS) by simulating each adaptive model with Air Force personnel data, and (3) develop a user's guide for effective understanding of adaptive model operations for successful field implementation.

Approach

Adaptive models selected for computer simulation were: (1) Drill and Practice, (2) Pacing, and (3) Monitoring (Algorithmic Regression). Detailed procedures, assumptions and parameter values employed in each of the three computer simulations are presented within the text. To facilitate comprehension, a user's guide approach to include detailed examples of reports to students, instructors and instructional managers has been utilized as a presentation format.

Results

Successful computer simulations of the: (1) Drill and Practice Model, (2) Pacing Model, and (3) Monitoring Model were accomplished. Model operations, recommendations for investigating parameter values other than those employed in the computer simulations and differential methods for model validation were included in the User's Guide. Additionally, the Phase II model simulations were combined with the Phase III Guide to provide a single integrated technical package for each model simulated. The technical package consists of: (1) a brief description of the model simulated, (2) a simplified explanation of *how* the model operates, (3) provides a scenario, using the Air Force data actually used in the simulation so the reader has a concrete, step by step example of how the model uses information to prescribe and adapt instruction to individual student performance, (4) gives examples of instructional objectives and instructional items used to attain such objectives, and (5) outputs reports to students and instructional personnel.

Conclusions and Recommendations

Computer simulations findings demonstrated the operational feasibility of three adaptive instructional models. It would be prudent of the Air Force to computer simulate at a minimum two additional models: (1) Concept Acquisition and (2) Dynamic Programming Models. Concept acquisition models formulate individualized strategies to ensure concept understanding in the least time possible.

Dynamic Programming models seek to optimize both student progress in real time as well as minimize total instructional costs for the entire instructional system.

It is further recommended that empirical validation of model effectiveness be conducted employing actual students in real time. Benefits of such research would include comparison of alternative instructional strategies, student attitudes toward computerized instruction and experience in optimizing instructional strategy effectiveness before widespread Air Force application.

PREFACE

The present study is one of a series of reports presenting adaptive instructional model research and computer simulations of three Adaptive Instructional Models (AIM).

To facilitate the widespread utility of these computer simulation findings, contained herein is a step-by-step user's guide. Further definitive findings are reported in AFHRL-TR-72-50 (I). "Analysis and Development of Adaptive Instructional Models for Individualized Technical Training: Phase 1." Research was accomplished in support of the Advanced Instructional System under Job Order 1193/OB/05. The research was conducted by the Center for Computer Assisted Instruction, Florida State University, Tallahassee, Florida, under contract F33615-71-C-1277 with the Air Force Human Resources Laboratory, Technical Training Division, Lowry Air Force Base, Colorado. Dr. Duncan Hansen was the Principal Investigator for Florida State University. Mr. Joseph Yasutake was the Division Project Scientist and Dr. Gerard M. Deignan was the Division Task Scientist.

Although many individuals contributed significantly to the successful completion of the Phase II and Phase III research efforts, Major Roger Grossel, Captain Edward Gardner, and Mr. Joseph Lamos are recognized for their constructive criticisms and suggestions. Dr. Robert Tennyson was indispensable in guiding this work to fruition.

The summary and other portions of the Phase I, II and III reports were prepared by Dr. Gerard M. Deignan.

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I. INTRODUCTION

Educational institutions are faced with the challenge of providing an adequate education to every student. At the same time, these institutions must design instructional systems that are cost effective. Research during the last decade in educational environments has demonstrated that individualized instruction is the most effective system in optimizing the learning process. The implementation costs of such a system have been prohibitive except in small experimental situations. Recent advancements in technology, especially in computer-managed instructional systems, show that the goal of individualization can be obtained within acceptable cost structures.

The Air Force training system has taken the initiative in designing an educational institution that meets the societal demands of quality learning for each individual while maintaining acceptable costs. The Air Force Human Resources Laboratory is currently developing an Advanced Instructional System (AIS) to be implemented in the technical training environment at Lowry Air Force Base (AFB). The AIS project began with a series of research studies to determine: (1) the basic specifications of the system, (2) the design of instructional models that would adapt to individual performance, (3) the methods for evaluating and measuring students given a totally individualized system, and (4) optimal instructional media. These investigations are to be used in the development of AIS courses at Lowry AFB.

The specifications study outlined a format for the development of seven AIS subsystem components. The present study reports the final design phase of one subsystem component - Adaptive Instructional Models (AIM).

Adaptive Instructional Models constitute the means by which instructional tasks, materials, media and resources are continually tailored or adapted to match the changing instructional needs, skills and interest motivations of individual students. To obtain a deeper understanding of the functions and interrelationships among various adaptive models, the reader is referred to a previous technical report (AFHRL-TR-72-50 (I)) entitled, "The Analysis and Development of Adaptive Instructional Models for Individualized Technical Training - Phase I. (Hansen, Brown, Merrill, Tennyson, Thomas, & Kribs, 1973).

Seven adaptive models were designed and categorized into three general areas: (1) *basic skill strategies*--drill and practice, and pacing models; (2) *instructional strategies*--concept, rule using, and problem-solving models; and (3) *management strategies*--monitoring, automata and dynamic programming models. These models were presented in the Phase I report, which discussed in detail the rationale, design and structure of each adaptive model.

Phase II, of the AIM contract, was to demonstrate the feasibility of using the models in the AIS. This report (AFHRL-TR-72-50 (II)) is a narrative description of the assumptions and rationale used in designing the three simulated models. This document presents the simulations, with emphasis on the characteristics of the models and samples of reports generated from the simulations. Concluding the report is a section on what was learned from the simulations and recommendations for extended study.

Overview of AIS

The AIS is a prototype, computer-based, individualized training system and research facility, designed to improve and maintain the cost-effectiveness of technical training. Individualization of technical instruction, computer management of instructional resources, and evaluation of instructional strategies are some of the AIS provisions expected to contribute considerably to the effectiveness and efficiency of technical training. Additionally, the AIS will serve as an evaluative test base for promising future instructional innovations.

Initially, the Advanced Instructional System will be implemented in three Air Force technical courses: (a) Precision Measuring Equipment, (b) Weapons Mechanic, and (c) Inventory Management. The AIS is designed to operate as a totally integrated computer-based system, capable of training approximately 2,100 students in the three courses with a projected 25 percent average reduction in training time. Time savings will be accompanied by training proficiency equal to or better than that of non-AIS graduates.

Overview of AIM

Adaptive Instructional Models are the means for analyzing student characteristics within the context of specific training tasks and objectives for the purpose of prescribing differential instructional conditions and resources for maximum training efficiency. These instructional models provide adaptability because instructional assignments and conditions are based upon and mediated by the characteristics and performances of each student. Most importantly, the models provide for a cybernetic, or feedback, process by which student data, the effectiveness of instructional treatments and resources are constantly updated to improve the overall training system.

AIM objectives. The objectives of the AIM project contribute directly to the goals of the Advanced Instructional System, namely, individualization of the training process, computer management of resources, use of cost-effective multi-media approaches, and training systems modularity.

Specifically, the objectives of AIM are stated as follows:

1. To provide monitoring of the student's characteristics and performance.

2. To provide a set of training decision rules that optimize student motivation and proficiency.

3. To provide a decision allocation procedure that optimally assigns instructional media, material, and incentive rewards according to the student's characteristics and performance.

4. To provide predictions of performance and time parameters for the student.

5. To provide for the scheduling of all instructional resources to lead to a minimization of training costs.

6. To provide procedures for monitoring and evaluating alternative adaptive model effectiveness according to appropriate matches among training task requirements, instructional resource availability, and specific individual differences.

Purpose of AIM Simulations

Simulation is a technique for modeling a particular process while manipulating variables so that possible outcomes can be observed. It is possible to represent and evaluate a real world situation without actually modifying or developing the environment being studied. The simulations described in this document allowed for the detailed specification and operationalism of AIMs in a computer-based, individualized, multimedia environment. This saved costly trial-and-error type efforts of development by allowing planning to proceed the development effort.

All of the necessary input and ouput information elements of each model's functional environment were demonstrated by the simulations. Operationally defined statements of model information requirements provided a link between the models and other AIS components, including the computer and computer software subsystems as well as the instructional materials, and media subsystems. Input data elements included: (a) student preassessment data; *e.g.*, Airman Qualification Exam (AQE) scores, (b) student performance data; *e.g.*, performance within lessons and instructional blocks; and (c) incentive history; *e.g.*, motivational preferences. An important contribution of the input and output data specifications in the AIM computer simulations was the explicit representation of the adaptive process. The representation of the adaptive process by which students' data were appropriately used as parameters in the context of AIS decision rules and procedures was an implicit goal in this effort. Lastly, the three AIM computer simulations provided a direct indication of how AIMs can be nested; *i.e.*, how one model can be controlled by another model. Thus, the instructional application of one model may be initiated by a higher-level model. For example, the simulated monitoring model may serve as a macro-decision making model for selecting a particular instructional treatment, such as the drill and practice model, which in turn may utilize the performance-contingent pacing model. Nested functional relationships are important features in the development of a range of adaptive models that can be coordinated within a master model to provide adaptive instructional monitoring, control, and decisions in a computer-based instructional system.

AIM Simulation Methodology

Considerable methodology for computer simulations exists, but computerized simulations have seldom been applied in the training area. The methodology used within this project represented concepts derived from computer simulation techniques, task analysis, and instructional systems theory. The sequence developed in this project followed seven steps: (a) specification of data elements and reports, (b) flowcharting of major components, (c) specification of typical protocols and input-output relationships, (d) specification of the quantitative processes in the model, (e) program implementation, (f) evaluation and revision, and (g) documentation. An explanation of each one of these steps follows:

Step 1: Specification of Data Elements and Reports

The purpose of this step was to specify what data elements and records were required. The data elements were:

1. *Preassessment data.* The preassessment data on a given student were categorized by aptitude, personality, and performance measures.

2. *Macro-performance data.* The system provided data on the lesson and block criterion tests according to task type and media as opposed to individual test performance indices.

3. *Micro-performance data.* On specific lessons the system provided response records which include item error data latencies, confidence, and state anxiety measures.

4. *Reports.* Reports were generated at three levels: (a) student level, which provided a prescription and feedback on performance in the lesson, (b) instructor level, which provided a report on students participating in a class, and (c) management level, a report on students participating in a block of instruction.

In addition, there were, when appropriate, specific item-by-item protocol report forms generated by the computer simulation. As will become clear in subsequent sections, each of these elements varied from model to model.

Step 2: Flowcharting of Major Components

For each model, the major components were identified, interrelated, and given a quasi-quantitative description. In order to maintain consistency, the following components were considered in each of the simulations:

1. *Initializing components.* Provides procedures for initializing or updating student data elements prior to instruction.

2. *Lesson prescription components.* The process by which a lesson was appropriately composed for a student.

3. *Lesson process components.* Permits adaptive interactive processes between students and the computer under the control of the model. Interactive processes refer to the frequency, format, and content of messages flowing between students and the computer.

4. *Lesson evaluation components.* Provides evaluative feedback to the student, instructor, and adaptive model.

5. *Special logic and calculation components.* Lessons requiring specialized logic or calculation components are separated and clearly identified.

Step 3: Specification of Typical Protocols and Input/Output Relationships

Given the availability of the preceding components, it was necessary to specify and implement the flow of information as it proceeded through the input, processing, and output states of the simulations. In Step 3 the exact protocol that represented the learning process for a given student was specified in detail. The specification process can be stated as follows:

1. *Specify the critical data elements for the protocols.* The subset of data elements essential for protocols at given states in the model were identified.

2. *List protocols at each major component point in the lesson format.* The accumulation of data in a particular protocol was specified.

3. *Specify the input, output devices which are controlled or monitored by the adaptive model.* Providing a statement of context for the simulation was a main goal of the simulations.

Step 4: Specification of the Quantitative Processes in the Model

The next step consisted of identifying, from a quantitative point of view, the constraints, constants, and parameters that would fit within appropriate mathematical, deterministic, and stochastic functions required for a realistic computer simulation. Realism was furthered by using appropriate Air Force information such as student aptitudes, course and lesson characteristics, concept topics, and objectives. In addition, data obtained by Vitola and Alley (1968) were used to provide Air Force trainee preassessment data for the simulations. The following specifications were given:

1. *Specify quantitative processes.* Each major component within the three simulations was quantitatively identified.

2. *Specify individual characteristics.* Individual differences likely to be encountered in an Air Force training environment were represented.

3. *Specify random distributions.* Distributions to be used for any of the random processes, in terms of distribution statistics which include means, variances, and ranges, were estimated.

Step 5: Program Implementation

At this point, a professional programmer implemented each of the simulations in A Programming Language (APL), a programming language which allows for student interaction simulation and simplifies complex mathematical functions. In some cases, revisions of the programs were based on the computer core requirements. These revisions were made with the intent of allowing for a minimum amount of core requirements so as not to overtax the ultimate AIS computing system with additional computing equipment demands.

Step 6: Evaluation and Revision

For each of the simulations, evaluation was pursued in terms of checks on student, instructor, and management reports. These reports were compared for realism as to score values and actual distribution; these error checks provided the input for reprogramming. In the vast majority of cases, the reprogramming consisted only of a change in the parameters for a given distribution or reformatting of the report labels.

Step 7: Documentation

In order to complete the simulations, each APL program was documented in detail. The remaining chapters of this report detail the three simulations. Each simulation implicitly assumed the AIS environment in which mastery by students of well-specified objectives was required, and students could not proceed until mastery was attained.

AIM Simulation Assumptions

The three simulated models, drill and practice, pacing, and monitoring, were developed according to rationales based upon empirical data and assumptions derived from instructional theories. The purpose of this section is to provide an overview of the simulation variables to show the similarities and differences of the three models.

Drill and practice simulation. The drill and practice model was designed to improve a student's accuracy in performing various skills. An individualized prescription of practice items was determined for each student in accordance with three basic assumptions:

1. Not all students require practice on the same set of skills. Consequently, items were included in the prescription in proportion to the student's prior mastery of the related skill as determined by a pretest.

2. Not all students learn at the same rate. Therefore, some students required more practice to reach mastery than other students. An index of student characteristics, based on preassessment data, was used to predict variations in the amount of practice required and prescribed items.

3. Some tasks are more difficult than other tasks and, consequently, require more practice to reach mastery.

4. An index of task characteristics which was predetermined on the basis of empirical evidence was also used in prescribing the number of practice items to be presented.

Underlying all drill and practice models is the fundamental assumption that a student's performance improves with practice until it approaches perfection. Therefore, the probability that the simulated student would respond correctly to an item from a particular task was incremented after each presentation of items for that task. Since feedback was provided after each response, even incorrect responses were assumed to be learning experiences and, accordingly, the probability of a correct response was increased regardless of the accuracy of the previous response. In addition, it was assumed that the amount learned from each presentation of an item varies from student to student. To incorporate this assumption into the model simulation, the increment in the probability of a correct response was a function of an index of student characteristics, namely his AFQT score. The following formula was used to determine the probability (P) of a correct response on the n^{th} presentation of an item related to a specific task:

$$P_n = P_{n-1} + (1 - P_{n-1})(.003 + .001Z)$$

where Z is the z-score equivalent of the student's Armed Forces Qualification Test (AFQT) score. The initial probability of a correct response was set at either 0.50 or the proportion correct on the pretest depending upon which is greater. Using the above formula, the probability of a correct response approaches but never reaches 1.00.

A final assumption of the drill-and-practice model was that performance would drop after practice ceases. Consequently, the model includes a review component. Items were selected for review on the basis of the relative importance of the associated objective (task) and the difficulty the student had with that item during the drill. Priority for selection was given to more important objectives and more difficult items.

Pacing simulation. The design of the adaptive pacing model was founded on two assumptions. First, it was assumed that self-paced, problem-solving rates would not yield an increase in problem-solving speed. Secondly, it was assumed that shaping a student's behavior by requiring him to respond at increasingly faster rates would ultimately result in an increase in problem-solving speed. In terms of the construction of the simulation, several further assumptions were made. The probability of a correct first answer was set at 0.5; *i.e.*, on the first attempt at the item the student had a 50 percent chance of answering it correctly. The probability of getting an answer wrong decays exponentially with the number of answers. Thus, the simulated student began responding with correct answers at a chance level and gradually improved with practice. And lastly, the student's latencies were assumed to decay exponentially with the number of answers. Since no student data other than that generated by him while performing the task were used by the pacing simulation, it was not possible to describe any particular student characteristics for this model. However, the pacing model was assumed to operate in conjunction with the drill and practice model; the student characteristics discussed in the preceding section describe the students in the pacing model.

Monitoring model simulation. This simulation was designed as a macro-model to be used as a monitor of the student's progress through an entire course. The previous simulations, drill-and-practice, and pacing, were micro-models concerned only with specific areas of a course. Therefore, the monitoring model used a variety of input variables to determine the student's individual assignment based on which micro-model, which media mode, and which measuring procedure was involved in the decision of instructional sequence. Equations, with assumed beta weights were generated for each of five time and five mastery treatments per lesson. Student characteristics were calculated using fifteen measures (*e.g.*, Armed Services Vocational Aptitude Battery (ASVAB) scores, AQE scores, task indices) which were correlated for each student's individual measures with all the other students' measures. The student's correlations were used in the equations to determine predicted score and time. The highest score of the five treatment equations was selected for the instructional sequence, along with the fastest time equation. Mastery for a given lesson was set at 80 percent correct on the criterion measures. The student's original correlation scores stayed the same within the simulation, but for each new lesson, the equations were different, requiring further calculations for assignment.

The monitoring model was designed according to these basic assumptions of instructional science:

1. Alternative instructional treatments can be developed for measured student differences.

2. No one treatment is "best" for all students.

3. There exist measurable individual difference variables which can be used to predict the most efficient treatment for a given student.

4. Individualized treatment assignments can reduce the time and cost of training without sacrificing performance.

II. DRILL-AND-PRACTICE MODEL

Drill-and-practice is defined as an instructional process which presents to the student a series of problems that require responses according to specified criteria. Two components of this model are immediate analysis of the student's response, and feedback to provide knowledge of results. The computer model can adapt the type and amount of problem practice on the basis of student characteristics, prior performance, and other training variables such as incentives. The goals of drill-and-practice computer strategies are: (a) to improve the student's accuracy, and (b) to increase his performance speed.

The first portion of this section presents a description of the data elements (the input and output measures) used in the simulation of the drill-and-practice model. A second section of the chapter is devoted to the major components of the simulation structure and the five types of output reports which were simulated. Tables of simulated reports, with annotated items, are presented for the Student Protocol Report, the Report to the Student, the Report to the Instructor, the Management Report, and the Item Summary. The chapter concludes with suggestions for future validation of the model.

The drill-and-practice model can be used for topic areas within each of the three courses (Inventory Management, Precision Measuring Equipment, and Weapons Mechanic) identified for development in AIS. The use of preassessment data, pretest scores, and task characteristics to generate lesson prescriptions individualizes the instruction to match both the student's and the institution's goals and objectives. This model also involves several options with respect to the sequencing of topics (objectives) and the amount of practice provided. The amount of practice is determined on the basis of: (a) preassessment data, (b) task characteristics, and (c) performance within the drill.

Data Elements

Data elements are defined as measurements and variables which are used to assess and prescribe the student's behavior. For the simulated drill and practice model three assessment variable groups were designed. First, preassessment data were used to identify the student's entering behavior to prescribe the initial instructional sequence. Second, task characteristics were the operational variables within the task. The third group, performance data, represented the student's actual behavior during the task.

Preassessment data. Measures of Airman pre-entry instruction behaviors were classified into categories: student profile and characteristics data. Contained within the student profile were Air Force personnel data such as the AQE scores, AFQT scores, educational level, prior work experience, performance on relevant courses, and biographical information. Student characteristics data included course specific aptitude scores, cognitive style indices, affective, attitudinal, and interest measures. These measures were accessed by the drill-and-practice model to formulate prescriptions, ultimately determining the amount of practice the student received and the size of the active item pool (a reflection of the individual's learning processes).

Task characteristics. A task index was used to determine the number of problems to prescribe for each objective. In general, the higher the index, the more problems a student was assigned. This index was directly related to the difficulty or importance of the objective. In a review session after drill and practice, an index of the relative importance of each objective was also used to select problems for the review. In addition, an index of the student's performance on each item within the drill was utilized to set priorities in the selection of problems within the objectives. Thus, the more important objectives were given priority over the less important objectives, and a problem which a student found more difficult was given priority over an easier item.

Performance data. Several indices of student performance within the drill were collected and used in the simulation. The student's history of correct responses to each problem was considered the most important variable. The number of consecutively correct responses was used to determine when the student had mastered a given problem; for this simulation the criterion was arbitrarily set at two consecutive correct responses. In addition, the percent correct of all responses to a given problem was computed to determine if the problem should be included in the final review. The number of times a student was presented a problem before he reached mastery was also collected. These data were used to summarize the performance in a student protocol report.

Another index of student performance which can be collected by the drill-and-practice model is response latency (time to perform a given amount of instruction). Mean latencies can be computed for each problem, each objective, and for the total drill. Latency data has not been included in the drill-and-practice simulation due to the obvious empirical uncertainties. But latencies could become part of the index for mastery, as could the two consecutive correct responses.

Simulation structure. The simulation of the drill-and-practice model was programmed in APL and run on an IBM 1500 instructional system at Florida State University CAI Center. The program was repeated 90 times with each repetition representing the performance of one simulated student between the pretest and the posttest. Five instructional objectives from Block III of the Precision Measuring Equipment course were used in this simulation.

Major Components of the Drill and Practice Simulation

The prescription, drill process, and review of the simulated model included the use of student preassessment and performance data and task characteristics for the construction of individualized lessons to be presented within the drill sequence. Decisions were made regarding the number of problems to be presented in a lesson and the sequence of problem types according to performance objectives. The simulation approach centered on the concept of instructional objectives and instructional prescriptions. The five objectives were representative of those found in the PME course, which range from 5 to 30 for a block of instruction. Each objective had a set of problems designed both to instruct the student, and to measure his mastery of the objective. The number of problems in each objective's set was arbitrarily fixed for this simulation. The number of problems varied across objectives as a demonstration of the model's generalizability.

For the purpose of the drill-and-practice simulation, the following preassessment measures were collected: (a) AFQT scores, (b) the AQE Mechanical Aptitude Subtest; (c) the AQE Administrative Aptitude Subtest; (d) the AQE General Aptitude Subtest; (e) the AQE Electronic Aptitude Subtest; (f) ASVAB Word Knowledge Test; and (g) the ASVAB Arithmetic Reasoning Test. In the simulation only the Airman's AFQT score was used as a variable in the decision process. The means, standard deviations, and intercorrelation matrices obtained from a sample of approximately 1,000 basic airmen (Vitola & Alley, 1968) were used to generate realistic preassessment data for the simulated students. These preassessment data were also used: (a) to establish the probability that the simulated student would respond correctly, and (b) to estimate the time for the student to complete the prescription. This involved the use of regression techniques plus stochastic processes using a uniform distribution.

Prescription. An individualized prescription was generated for each student per objective on the basis of his pretest scores, task characteristics, and student characteristics as represented in Figure 1. The index of pretest score was defined as 1 minus the proportion correct of those problems in the pretest relating to each objective. For the purposes of the simulation, the pretest scores were randomly generated for each objective. It was assumed that even a bright student might never have had any prior experience with a particular objective and would perform poorly on the pretest, therefore, the following conditions were imposed upon the simulation exercise. For a given simulated student, there was no intentional correlation among scores on the five instructional objectives, nor was there a correlation between the total pretest score and any preassessment data for that student.

The index of task characteristics in the model has been called a selection index and was predetermined for each objective by the course development component of AIS. This task selection index was directly related to the importance of the objective or the difficulty in learning the objective. Accordingly, more practice was provided for objectives with higher selection indices. For the purposes of the simulation, the task selection indices were randomly generated numbers ranging from 1 to 5.

The third variable used to generate prescriptions was based on student characteristics and was an index of the amount of practice a student needed to attain mastery. For the purposes of this simulation, the student characteristic index was a function of his AFQT score and ranged from 1 to 5. (On the basis of future results obtained from employing this model with actual students, the student characteristics index can be refined to reflect additional preassessment data.)

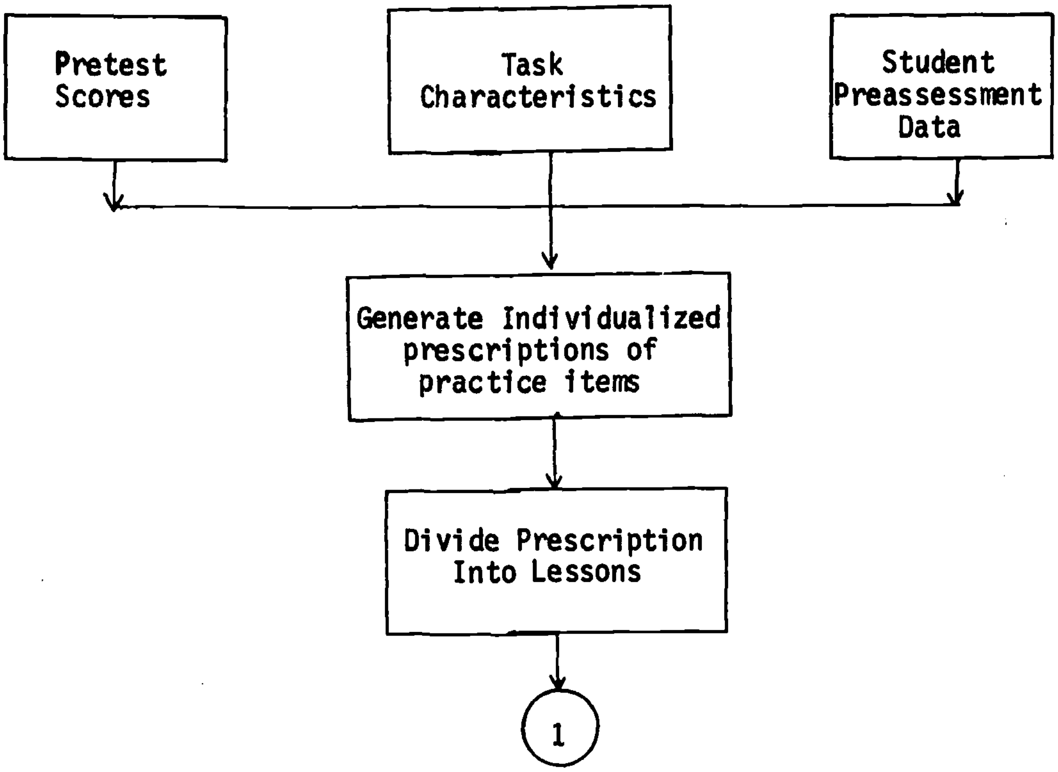


Figure 1.--First component of the drill-and-practice simulation-Prescription.

To determine the number of practice problems to present to a student for each objective, the following formula was used: (1 - pretest score) x (selection task index) x (student index). The result of this multiplication was rounded up to the next whole number.

The model required that for each objective, there must be a large pool of problems from which to select the practice problems. The specific problems prescribed for each objective were randomly selected from this pool. If there were fewer problems in the pool than the prescription required, the model would select all problems available.

The next step in the model was to divide the prescription into lessons of approximately 20 to 25 problems each. Whenever possible, all problems relating to a particular objective were assigned to the same lesson. The problems for each lesson composed a lesson pool and were randomly sequenced.

Drill process. In order to optimize the frequency with which a problem was presented, a subset of the lesson pool called the "active pool" was designated (Figure 2). A number specifying the active pool size or optimal block size could be determined by statistical regression techniques on the basis of both student and task characteristics. For the purposes of this simulation, the active pool size was a randomly generated number from 10 to 15, since the empirical relationships were unknown.

In the simulated drill process, the active pool was filled with problems from the lesson pool. The items were presented sequentially, looping back to the first item after the last problem in the active pool. When the student met the criterion of correctly responding to two successive presentations of a given item, the item was deleted from the active pool and moved to a review pool. A new problem was brought from the lesson pool. When there were no more new problems in the lesson pool, the active pool was allowed to decrease to a minimum size of 5 after which an item was selected from the review pool to maintain this minimum size of the active pool. This process continued until all problems had been mastered. The same procedure was employed for the remaining lessons.

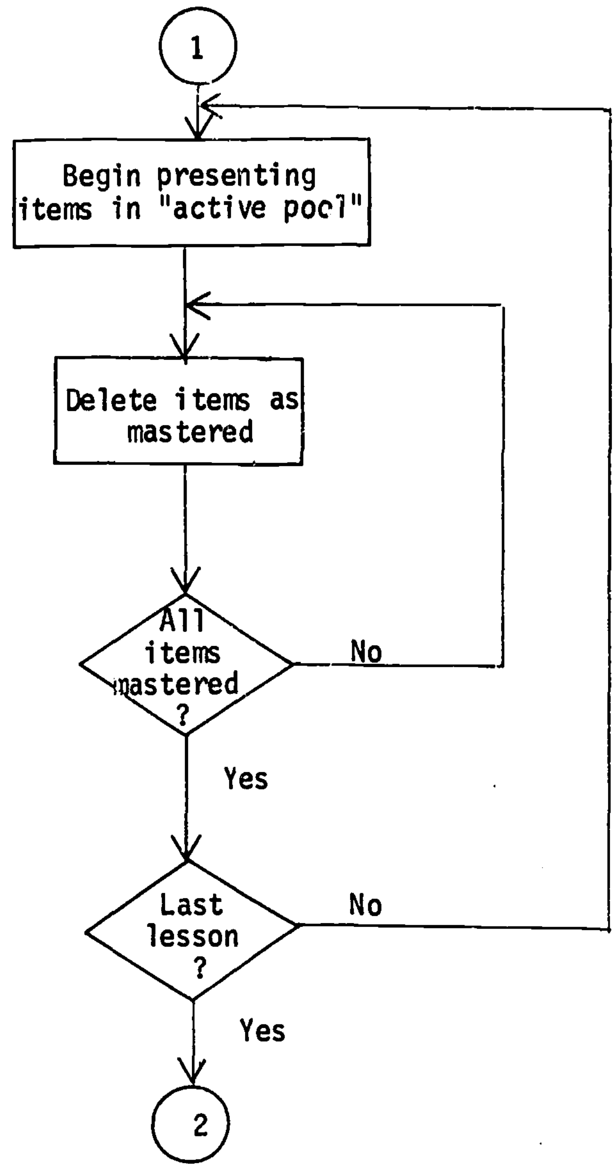


Figure 2.--Second component of the drill and practice simulation-Drill process.

For the purposes of the simulation, the "correctness" of the simulated student's response was a randomly-generated number based on the probability that the student would respond correctly on that particular presentation. At the beginning of the simulation, the probability that the student would respond correctly to any given item was the pretest score for each objective, but no less than 0.50. For each presentation of a problem for a given objective, this probability was incremented as a function of the student's AFQT score. This probability was incremented separately for each objective and asymptoted less than one. For both correct and incorrect responses, the probability that the student would answer correctly on the following presentation was increased, since it was assumed that learning could occur from an incorrect response if feedback was provided.

Review. When the simulated student had completed all the lessons composing the prescription, a review lesson was constructed (Figure 3). The criteria for selecting items for the review lesson were: (a) the importance of the objectives to which the problem belonged, and (b) the performance of the student on that problem within the drill lessons. Problems belonging to objectives which have higher relative importance were given priority. Also, within each objective, the problems with which the student had the greatest difficulty (as defined by more than the average number of presentations required to reach mastery) were given priority over the easier problems for that objective. The process for presenting the problems in the review lesson was similar to the process employed within each of the drills except that the criterion for deleting an item from the active review pool was one correct response. This review lesson was composed of 25 problems which were randomly ordered and presented until the student had answered each one correctly. When the student had finished the review lesson, he was ready to go on to the posttest.

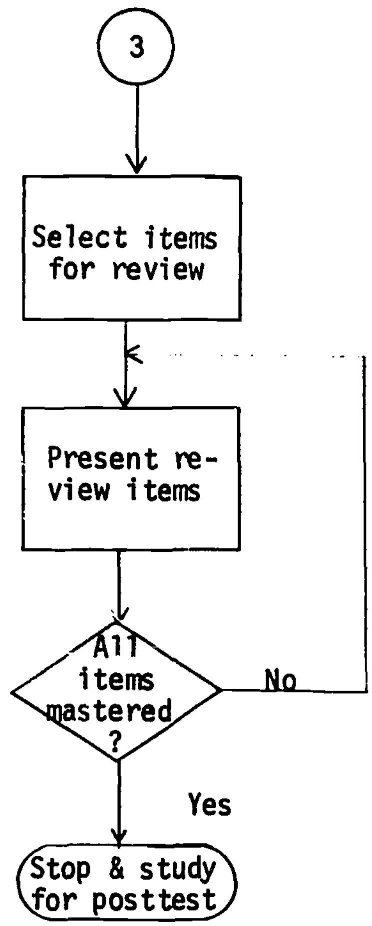


Figure 3.--Third component of the drill and practice simulation-Review.

Output Reports

Five reports were designed for the drill-and-practice model simulation to illustrate the type of information which could be collected. The five sample reports from the simulation model will be presented and discussed. They are:

1. The Student Protocol Report
2. The Report to the Student
3. The Report to the Instructor
4. The Management Report
5. Item Summary

Student protocol report. The student protocol report was a detailed record of a student's performance as he progressed through the drill. It was made up of four major sections: (a) initialization information, (b) detailed response records, (c) item summary, and (d) instructional objective summary. Each of these sections will be presented in a simulated table on one student including annotations of the tabled information. Table 1 shows a simulated protocol for a given airman. The initialization information identified the student and generated his individualized prescription of practice items. This data allowed the instructor to review the type of decisions made for each student.

The second part of the student protocol report consisted of a series of records corresponding to each response the student made as he proceeded through the drill. The detailed response records, as is shown in Table 2, began with, "The assignment for lesson 1 is . . . ." A prescription may have been broken into two or more lessons, and this line indicated the number of items from each objective assigned to lesson 1, 2, etc.

Following this information on student responses, an item summary was printed out as simulated in Table 3.

Finally, there was an overall summary of the student's performance. The simulated objective summary is simulated Table 4.

Tables 1 through 4 illustrate with simulated data, the components of a complete student protocol report in the drill-and-practice model. A second set of reports for the drill-and-practice model was that report intended for the student himself.

Report to the student. The student report was divided into two sections; the first section was printed out at the student's terminal or on the nearby line printer at the beginning of the drill to inform him of the prescription he was to follow. In addition to student identification information, it provided the name of the lesson, the number of items assigned, and the estimated time for the student to complete the prescription. This preinstructional report to the student is simulated in Table 5.

The second part of the report to the student was printed after he had completed the prescription to inform him of his progress and performance. This again included student identification information. The evaluation was intended to give the student an indication of which objectives he needed to emphasize while studying for the posttest. A sample is shown in Table 6.

These preinstructional and postinstructional reports were made directly to the student. A third major reporting instrument in addition to the Student Protocol Report (for an individual student) and the Report to the Student, is the Report to the Instructor.

Report to the instructor. The instructor report summarized the performance of 15 students on the same drill and practice lesson and was designed to facilitate the instructor's evaluation of their progress. A table of pretest results for each student as well as the mean and standard deviation is provided. A similar table summarized the student's performance in terms of the percent correct. Table 7 depicts simulated information on a report to the instructor.

Management report. The fourth type of report simulated, the management report, was calculated and printed after each group of 45 students had completed the lesson (Table 8). This report summarized their pretest results, the number of items assigned, and their performance within the drill. In addition there was a cumulative report providing similar information regarding all prior students who had completed this lesson (Table 9). The management report facilitated the evaluation of the instructor's performance. A secondary purpose of this report was to aid in the evaluation of the course for revisions.

Cumulative management report. Except for listing the participating students' AFSNs, the information contained in the cumulative management report was the same as that in the management report (Table 8). The data reported was cumulative on all students who had taken the particular lesson and who were included in the current management report.

TABLE 1

Simulated Drill-and-Practice Student Protocol Report
Part 1: Initialization Information

AFSN [1]	NAME	COURSE [2]	BLOCK [3]	LESSON [4]	INSTRUCTOR	DATE
768901	Jones, A.E.	PME	III	01	Clark, D.	08/24/72

Preassessment Data [5]

AQE Mech	AQE ADM	AQE Gen	AQE Elec	AFQT	Verbal	Arith
61.80	73.26	76.78	55.47	49.56	21.15	18.83

LESSON TOPIC: [6] Resonance in Tuned LRC Circuits

Instructional Objective Code [7]	1	2	3	4	5
Objective Selection Index [8]	1	2	2	2	3
% Correct in Pretest [9]	96	66	24	26	7
Number of Items Prescribed [10]	1	3	7	7	12
Number of Items Assigned [11]	1	3	7	7	12
Total Number of Items in Pool [12]	30				
Number of Items in Active Pool [13]	13				

[1] *AFSN - Armed Forces Serial Number.* Due to system limitations, only six digits rather than a full social security number were recorded. These numbers were randomly generated for the simulation.

[2] *Course.* Course titles were abbreviated.

[3] *Block.* Courses were divided into blocks and labeled with Roman numerals.

[4] *Lesson.* The specific lesson being taught was recorded by number.

[5] *Preassessment data.* Preassessment measures were generated to match test statistics which were derived from a sample of 1,000 airmen (Vitola & Alley, 1968).

[6] *Lesson topic.* Lesson content was briefly described.

[7] *Instructional objective code.* Each instructional objective was numerically coded.

[8] *Objective selection index.* The selection index numerically assigned each objective according to its difficulty and importance. More items were assigned for objectives with high selection indices. For the purposes of the simulation, the selection indices were randomly generated numbers from 1 to 5.

[9] *Correct in pretest.* The percent correct of responses to the pretest was recorded separately for each objective. For the purposes of the simulation, these scores were randomly generated.

[10] *Number of items prescribed* The number of items prescribed for each objective was determined by the following formula: (1 - pretest score) x (selection index) x (student index). (For the purposes of the simulation, the student index was a function of the AFQT score only.)

[11] *Number of items assigned.* Generally, this was the same as the number of items prescribed unless more items were prescribed than were available.

[12] *Total number of items in pool.* This was the sum of items assigned across all the objectives.

[13] *Number of items in active pool.* The size of the active pool was determined on the basis of both student and task characteristics. The active pool size in this simulation was randomly varied from 10 to 15.

TABLE 2

Simulated Drill-and-Practice Student Protocol Report
Part 2: Detailed Response Records

THE ASSIGNMENT FOR LESSON 1 IS . . .

	OBJ 1	OBJ 2	OBJ 3	OBJ 4	OBJ 5
# of items	1	3	7	7	12

DETAILED RESPONSE RECORDS

TRIAL[1]	ITEM[2]	OBJ. CODE[3]	# PREV ENCOUNT.[4]	PREV COR.[5]	INTERVEN-ING ITEMS[6]	PROB COR.[7]	RESP[8]	PREV MAST.[9]
1	3	5	0	0	1	0.50	0	0
2	29	3	0	0	2	0.50	0	0
3	6	4	0	0	3	0.50	1	0
4	41	5	0	0	4	0.50	0	0
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
96	14	5	9	1	5	0.59	1	0

[1] *Trial.* Each presentation was numbered sequentially.

[2] *Item.* The number of the item was presented.

[3] *Objective code.* The number of the objective this item represented was recorded.

[4] *#Previous encounters* This numbered the times the same item was previously presented within the same lesson.

[5] *Previous correct.* This indicated the number of consecutive correct responses to previous presentations of the same item.

[6] *Intervening items.* The difference between the current trial number and the trial number of the immediately preceding presentation of the same item was indicated. (Note: for the first presentation of each item, this number was meaningless since it was the same as the trial number.)

[7] *Prob. Correct.* This was the probability of a correct response to the current presentation.

[8] *Response.* A "1" indicated a correct response and a "0" indicated an incorrect response to the current item.

[9] *Previously mastered.* This indicated the number of items mastered before the current trial.

TABLE 3

Simulated Drill and Practice Student Protocol Report
Part 3: Item Summary

Item[1]	Obj. Code[2]	# of Responses[3]	% Correct[4]
3	5	2	100
4	5	4	80
5	4	4	55
6	4	2	100
8	2	3	66
9	5	6	66
.	.	.	.
.	.	.	.
.	.	.	.
44	2	5	60

[1] *Item*. The number of the item is given.

[2] *Obj. code*. The number of the objective to which the item belongs is identified.

[3] *# of responses*. The number of responses to the item up to and including the response at which mastery was attained.

[4] *% correct*. The percent of the above responses which were correct.

TABLE 4

Simulated Drill-and-Practice Student Protocol Report
Part 4: Instructional Objective Summary

Obj. Code[1]	# of Items[2]	# of Responses[3]	Presentations Per Item[4]
1	1	2	2.00
2	3	15	5.00
3	7	21	3.00
4	7	26	3.71
5	12	64	5.33
Total[5]	30	128	4.26

[1] *Objective code*. The number of the objective summarized in that row.

[2] *# of items*. The number of items assigned for the given objective.

[3] *# of responses*. The total number of item responses for the given objective.

[4] *Presentations per item*. The number of responses divided by the number of items.

[5] *Total*. This gave the total number of items, the number of responses up to mastery, and the mean number of presentations per item for the lesson.

TABLE 5

Simulated Drill and Practice
Report to the Student Before Lesson

AFSN	NAME	COURSE	BLOCK	LESSON	INSTRUCTOR	DATE
768901	Jones,A.E.	PME	III	01	Clark, D.	08/24/72

Lesson Topic-
Resonance in tuned LRC circuits

*** Before Lesson***

Assignment

The number of items you have been assigned is-[1]
30

The estimated number of minutes for you to complete this assignment is-[2]
60.C

[1] *Assignment.* This indicated the total number of the items prescribed for the student.

[2] *Time estimate.* This was the estimated time (in minutes) needed for the student to reach mastery of all the items. The time for review was excluded. It was assumed that the average student needs six trials to pass each item and 20 seconds for each trial.

TABLE 6

Simulated Drill-and-Practice
Report to the Student After Lesson

AFSN	NAME	COURSE	BLOCK	LESSON	INSTRUCTOR	DATE
768901	Jones, A.E.	PME	III	01	Clark, D.	08/24/72

*** After Lesson[1] ***

# of[2] Items	# of[3] Trials	%[4] Correct	Time[5] (Min.)
30	128	57.4	43.6

% Correct for Each Objective[6]

Obj.1	Obj.2	Obj.3	Obj.4	Obj.5
45.4	48.6	53.3	68.4	56.6

[1] *After lesson*. This represented the overall result of the student's performance in the lesson.

[2] *# of items*. This indicated the total number of items the student completed during the lesson. In general, the student should complete all the items in the lesson.

[3] *# of trials*. This indicated the total number of trials attempted by the student.

[4] *% correct*. This shows the ratio between the number of successful trials to the total number of trials.

[5] *Time*. The total time spent by the student in the lesson is recorded in minutes.

[6] *% correct for each objective*. For each objective the percent of the responses that were correct was shown to indicate the student's strengths and weaknesses.

TABLE 7

Simulated Drill-and-Practice
Report to the Instructor

COURSE	LESSON	LESSON TOPIC
PME	01	Resonance in Tuned LRC Circuits

Dates[1]	Instructor	Enrollment
08/24/72-08/31/72	D. Clark	15

Pretest Results (% correct)[2]

Obj.1	Obj.2	Obj.3	Obj.4	Obj.5	Total	AFSN
4	63	99	99	75	75	898185
31	98	71	55	84	73	449883
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
Means						
37	56	66	56	51	55	
Standard Deviations						
18.0	27.1	27.1	29.0	32.2	13.6	

Performance Summary (% correct)[3]

Obj.1	Obj.2	Obj.3	Obj.4	Obj.5	Total	AFSN
100	100	66	100	75	86	506940
100	55	100	100	83	78	898185
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
Means						
62	73	77	69	70	64	
Standard Deviations						
24.3	19.5	20.1	19.7	16.0	10.4	

[1] *Dates.* Individual students may have taken the lesson on any day within the specified period.

[2] *Pretest results.* The percent correct on the items for each objective, as well as the percent correct for the total pretest, was given for each student. Since there were varying numbers of items per objective on the pretest, the total score was a weighted average of the objective scores (calculated from the objective selection index, Table 1). The students were ranked from high to low on the basis of their total pretest score. The means and standard deviations for each objective and the total pretest were given.

[3] *Performance summary.* This section of Table 7 gives the percent correct of each student's responses up to and including mastery on each item for each objective and for the total drill. The means and standard deviations are also given. Again the students were ranked from high to low on the basis of their percent of correct responses in the drill.

TABLE 8

Simulated Drill-and-Practice
Management Report

COURSE	BLOCK	LESSON	DATES	REPORT NUMBER[1]	INSTRUCTOR
PME	III	01	08/24/72-08/31/72	02	Clark,D.

Participating Students[2]

569547	203800	376074	899106	396353	123656	536049
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.

Number of Students[3]
45

Pretest Results (% correct)[4]

	Obj.1	Obj.2	Obj.3	Obj.4	Obj.5	Total
Mean	50	46	49	50	46	48
S.D.	27	29	26	27	29	28

Assignment (# of items)[5]

	Obj.1	Obj.2	Obj.3	Obj.4	Obj.5	Total
Mean	2	3	3	3	5	16
S.D.	1	1	1	1	3	6

Performance Summary (% correct)[6]

	Obj.1	Obj.2	Obj.3	Obj.4	Obj.5	Total
Mean	72	70	65	69	65	68
S.D.	23	20	19	19	19	20

[1] *Report number.* These reports were numbered sequentially for ease in filing.

[2] *Participating students.* The AFSNs of the students included in the report were listed.

[3] *Number of students.* This indicated the number of students included in this report.

[4] *Pretest results.* The means and standard deviations of the pretest scores for each objective were recorded in terms of percent correct. The total pretest result was a weighted average calculated using the objective selection index from the student protocol report (Table 1).

[5] *Assignment.* The means and standard deviations of the number of items assigned for each objective and for the total drill were recorded.

[6] *Performance summary.* The means and standard deviations of the percent correct of the responses during the drill up to and including mastery were recorded for each objective and for the total drill. The total was a weighted average (same as the pretest results).

TABLE 9

Simulated Drill-and-Practice
Cumulative Report

COURSE	BLOCK	LESSON	DATES	REPORT NUMBER	INSTRUCTOR
PME	III	01	07/15/72-08/31/72	02	Clark,D.

Number of Students
90

			Pretest Results (% correct)			
	Obj.1	Obj.2	Obj.3	Obj.4	Obj.5	Total
Mean	49	49	52	52	49	50
S.D.	26	29	28	28	30	29
			Assignment (# of items)			
	Obj.1	Obj.2	Obj.3	Obj.4	Obj.5	Total
Mean	2	3	3	3	5	16
S.D.	1	1	2	2	3	6
			Performance Summary (% correct)			
	Obj.1	Obj.2	Obj.3	Obj.4	Obj.5	Total
Mean	70	69	67	69	68	68
S.D.	23	20	19	19	19	20

Item summary. The fifth simulated drill-and-practice report, the item summary report, was requested after a large number of students had completed the lesson. For each item the difficulty index and the number of students who were assigned the item were reported. This report was intended for use by the instructional development and evaluation component of AIS to facilitate the evaluation of the instruction and also to identify any problems which should be replaced. Table 10 depicts a simulated Item Summary Report.

Future Validations and Model Refinement

Controlled study groups, alternative model development, and new estimation procedures might be pursued to validate the simulation procedures. The FSU team recommends that an alternative strategy be utilized that both maximizes review mastery and minimizes training time. Mastery levels can indicate the effectiveness of the prescription process and the criterion for problem elimination. Time saving should reflect the quality of the prescription and block size process. The extension of latency criteria and the elaboration of the task index will help interrelate the behavioral findings with the task structural features found in technical training. The simulated drill-and-practice model was designed using, in part, assumed parameters. To operationalize the model, these parameters, optimum block size, task selection index, index of student characteristics, criterion for mastery, and size of lesson, need empirical investigation. This should assist in the refinement and generalizability of the model.

TABLE 10

Simulated Drill-and-Practice
Item Summary

COURSE	BLOCK	LESSON	DATE
PME	III	01	08/31/72

Number of Students
90

Item[1]	Obj. Code[2]	N[3]	% Correct[4]
1	4	30	61
2	2	44	74
3	1	32	67
4	3	40	74
5	4	35	70
.	.	.	.
.	.	.	.
.	.	.	.
44	5	38	65

[1] *Item*. The number of the item presented to the student is shown.

[2] *Obj. code*. The number shown represents the objective to which the item belonged.

[3] *N*. The number of students presented the item is given.

[4] *% correct*. The number represents the percent correct of all responses.

III. PACING MODEL

Pacing models are defined as instructional systems which control the amount of problem-solving time permitted a student based upon his performance. The goal of the pacing model is to increase problem-solving speed without jeopardizing accuracy. The student's accuracy or mastery level takes precedence over his problem-solving speed. However, if the learner's efficiency can be improved without adversely affecting his accuracy, then one of the major goals of AIS can be achieved; *i.e.*, learner efficiency.

The pacing model was simulated to demonstrate the feasibility of having an adaptive instructional system in the AIS which increases problem-solving speed while not debilitating accuracy. This section is introduced with a description of the model's general characteristics and data elements. The second section presents the major components of the simulated pacing model and four types of output reports. The section concludes with a narrative on the validation and recommendations for future refinements.

The pacing model, specified here, was designed for use within a wide range of problems or study tasks. It should be especially useful for reading, study, and problem-solving tasks of known difficulty levels. The objective of task flexibility was accomplished by varying the time. For example, if performance was high, the time allowed for problem-solving was decreased, and if performance was low, the student was given more time to solve the next set of problems. The pacing model used no data other than that generated by the student within the task context; that is, the decision structure of the pacing algorithm uses only individual, in-task performance data as input. Future developments of the model will include preassessment of task data as factors for accurately predicting performance effective presentation rates. The model will maximally adapt accuracy and speed within a sequenced task structure.

Data Elements

The data elements used in the simulated pacing to assess student behavior were task characteristics (operational variables of the task) and performance data (within-task behavior). Preassessment data; *e.g.*, AQE and AFQT scores, educational level, were not used directly within the simulated pacing model. All input data used in the decision structure of the simulation came from within-task performance measures. The decision structure used a set of rules based on an individual's in-task performance data to arrive at a particular decision by a systematic and efficient means.

Task characteristics. Since the pacing algorithm was adaptive to the individual's performance, and it was that performance which was affected by task difficulty, it followed that the algorithm was adaptive to task difficulty features. The algorithm worked best with homogeneous problem sets, but task difficulty *per se* needed no rigid control. The pacing model may be used in study or problem-solving sequences which are presented via a computer-controlled typewriter or display device. No other medium is as functional as the computer interactive terminal because performance reports must be presented to the student while he is taking a paced lesson.

Performance data. Within the pacing model two types of performance data were utilized to determine the amount of the increase or decrease in the time allowed for the next set of problems: (a) the number of correct responses, and (b) latency data (student time to respond) were used to determine whether the student's problem-solving time was to be increased, decreased, or stabilized.

Simulation Structure

The pacing model was selected for simulation from among the seven adaptive instructional models (Hansen *et al.*, 1972) because it not only improved effectiveness of the learning process, but also increased the efficiency of the process. The simulation used the APL computer language for use on the CAI Center 1500 IBM system. The program simulated a total of 90 students to demonstrate sufficient output for analysis of the pacing model.

Major Components of Pacing Model Simulation

The components of the pacing model simulation were: (a) a set of algorithmic decision rules, (b) student performance data in the form of correct responses and latencies, (c) informative feedback to the student while he was performing the task, and (d) summative reports to personnel at the instructor and supervisor level.

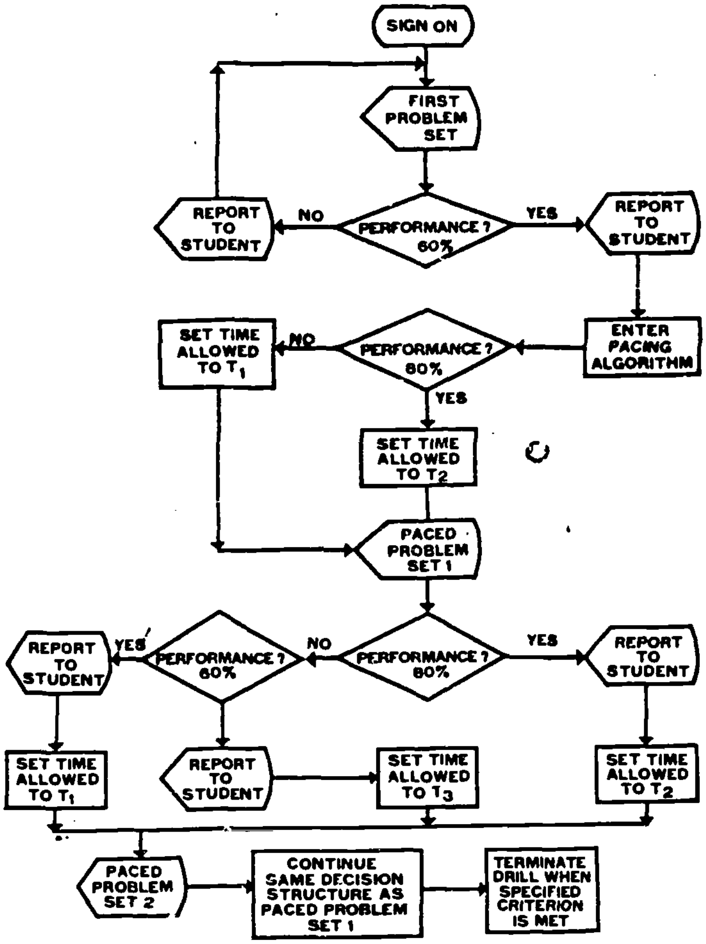
These components functioned together in the manner shown in Figure 4.

When the first set of problems was presented to the student, he was given as much time as he needed to solve them. If his performance on this problem set was equal to or greater than 60 percent correct, he entered the pacing algorithm. If his performance was below 60 percent correct, he did not enter the algorithm, but was given a new problem set and allowed to work through it at a self-paced rate. Immediately prior to that presentation, the student was given a message encouraging him to improve his accuracy. Using this procedure, the student did not enter the pacing algorithm until he had achieved sufficient mastery of the material. Entering the algorithm prior to obtaining a degree of mastery was assumed to be maladaptive to both his future performance and problem-solving speed.

When the student did perform at a 60 percent accuracy level or better, the pacing algorithm controlled the problem-solving time allowed for the next set of problems. Several decision rules became functional at this time.

1. If performance was greater than or equal to 80 percent correct, then the problem-solving time allowed for the next set of problems was set at the mean of (a) his current time allowed, and (b) the current mean latency (T_2). Initially, this decreased the amount of time allowed, yet it did not overtax the student's capabilities. Rather, it served as a stabilizing mechanism, whereby the problem-solving time was gradually reduced.

2. If performance was equal to 60 percent correct, then the problem-solving time allowed for the next set of problems remained unchanged (T_1).



T1 = time allowed remains unchanged

T2 = 1/2 (current mean response latency + current time allowed)

T3 = 1/2 (current time allowed + last latency setting for which the student correctly answered 80% of the problems)

• If performance < 60% on two consecutive problem sets then time allowed on next problem set is set equal to the last latency at which the student answered correctly 80% of the problems

Figure 4.--Pacing Model Flowchart

3. If performance was less than 60 percent correct, the problem-solving time allowed for the next set of problems was set at the mean of (a) the current allowed time and, (b) the next lower allowed time during which the student correctly answered 80 percent or more of the problems (T_3).

4. If the student obtained a 60 percent level of accuracy on two consecutive problem sets, his allowed time for the next set of problems was set at the next lower allowed time during which the student correctly answered 80 percent of the problems, rather than T_3.

5. The paced sequence was terminated when the student's performance (accuracy and speed) met a specified criterion. This criterion was arbitrarily set at a performance greater than or equal to 80 percent correct, when the absolute change in maximum time allowed was less than the larger of (a) two seconds or, (b) the standard deviation of the latencies of the last problem set. That is, the paced sequence was terminated when performance was high and when there was no evidence of any further improvement in problem-solving speed.

At the conclusion of each problem set the student received a record of his performance, and feedback which informed him of the decision made by the computer to either increase, decrease, or stabilize his problem-solving time. When a student completed a lesson, a student protocol report was immediately generated. Similarly, when 45 students taking a particular lesson had terminated, a management report and an instructor report were generated. These reports were valuable for providing immediate knowledge of results to persons at all levels in the instructional process. With detailed reports available, irregularities within the global instructional system, as well as within the pacing model itself could be identified and corrected.

Output Reports

Four reports were designed for the pacing model simulation to illustrate the variety of information which could be collected. These reports provided feedback to the student so that he could participate in the learning process; and data to the instructor for keeping an updated record on each student. Such data are useful and necessary for the maintenance and revision of the proposed AIS. The four sample reports from the pacing model simulation were:

1. The Student Protocol Report
2. The Report to the Student
3. The Report to the Instructor
4. The Management Report

Student protocol report. The student protocol report provided a detailed description of a student's performance on a particular lesson. The report gave data on three major sections: (a) initialization information; (b) response records on each problem set; and (c) summaries on number of problem sets and learning latencies. These sections will be presented by a table of simulated data on one student with annotations of the tabled information. Table 11 shows an example of a protocol report simulated for a given airman.

Student report. A report to the student was provided immediately after completion of a problem set. It included the number of problems seen, the number correct, the number of items the student failed to answer in the time allowed, and his average response time. In addition, feedback was given to the student regarding his current performance level, and suggestions were given about how he should respond on the next problem set. Table 12 shows an example of a pacing model report simulated for a given airman.

Instructor report. To maintain current updates on student performance the instructor's report provided a student profile per lesson. Along with the initialization data, the report presented the mean latencies for the first and last problem sets per student. The difference between these two latency figures indicated to the instructor the amount of change in the student's problem-solving speed. Table 13 contains an example.

Management report. Two supervisory reports were designed for the simulated pacing model to give summary data on the total lesson performance of currently enrolled students, and a cumulative analysis on all current and previously enrolled students. These reports were issued for lessons within blocks. The Management Report was issued immediately after enrolled students completed a lesson. This report (Table 14) allowed the supervisor to review student group progress on the various lessons and blocks. Combining this knowledge with the Cumulative Management Report (Table 15) the supervisory personnel had the data necessary for locating potential revision areas.

Validation and Future Refinements

Validation of the pacing model should assess its effect upon reading effectiveness and efficiency. Consequently, there should be more use of the model during the early blocks of a course with fewer and fewer requirements during the later blocks. This would be a direct indication of the efficacy of the model. Secondly, the decision rule by which adjustments are made in the pacing presentation should be varied in a systematic manner so as to find the one which improves reading rates the most. Lastly, investigation can be pursued into the frequency with which the model is applied to given students, studying the long-term

TABLE 11

Simulated Pacing Model
Student Protocol Report

AFSN	NAME	COURSE	BLOCK	LESSON	INSTRUCTOR	DATE
768901	Jones,A.E.	PME	III	01	Clark,D.	08/24/72

Prob. Set[1]	Time Allowed[2]	Number Timeouts[3]	Number Correct[4]	Mean Latency[5]	Latency S.D.[6]	Change[7]
1	100.00	0	4	25.31	5.89	-37.34
2	62.65	0	3	21.51	4.66	0.00
3	62.65	0	3	24.97	4.11	0.00
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
32	6.47	1	4	4.61	1.40	-0.93

Summary[8]

# of Sets[9]	Mean Set Latency[10] First	Last	Change[11]
32	25.31	4.61	-20.69

[1] *Problem set.* The listing contains the problem sets within the lesson taken by the student.

[2] *Time allowed.* The maximum time limit expressed in seconds, within which the student must respond, is given for each problem set.

[3] *Number of timeouts.* The number represents the times the student failed to respond within the time allowed.

[4] *Number correct.* The number of questions correctly answered by the student is given for each problem set.

[5] *Mean latency.* The average response time (seconds) to the questions within a problem set is shown.

[6] *Latency S.D..* The standard deviations of the student's response times are given per problem set.

[7] *Change.* The number shown represents the amount of the increase or decrease in the time allowed from one problem set to the next.

[8] *Summary.* These columns summarize the protocol report.

[9] *# of sets.* The number given is the total problem sets encountered.

[10] *Mean set latency (first-last).* The mean response latency is given for the first and last problem sets.

[11] *Change.* The figure represents amount of the decrease in response latency from the first to the last problem set.

effects on their reading and problem-solving rates. The goal is to determine the algorithm which promotes increase in problem-solving speed and has the most lasting effect. In the future, decision algorithms should be considered that incorporate variables such as a student's confidence in his performance and reading rate. The incorporation of preassessment variables also seems appropriate.

TABLE 12

Simulated Pacing Model
Student Report

AFSN	NAME	COURSE	BLOCK	LESSON	DATE
768901	Jones,A.E.	PME	III	01	08/24/72

This is a summary of your recent performance

Number of Items[1]	Number Correct[2]	Number of Timeouts[3]	Average Response Time (Sec)[4]
5	3	0	25

You only answered 3 problems correctly that time. I will give you the same amount of time for the next set of problems. Try to get them all right this time.[5]

[1] *Number of items.* The number of items in the immediately preceding problem set is given here.

[2] *Number correct.* The number of problems correctly answered is shown.

[3] *Number of timeouts.* The number of times items were not answered in allotted time.

[4] *Average response time (sec).* The mean response latency of the immediately preceding items is expressed in seconds.

[5] *Feedback is given about performance and the state of the pacing procedure.*

TABLE 13

Simulated Pacing Model
Instructor Report

COURSE	BLOCK	LESSON	DATES	INSTRUCTOR
PME	I	01	08/11/72-09/03/72	Clark,D.

Number of Students[1]
15

AFSN[2]	# of Sets[3]	Mean Set Latency[4] First	Last	Change[5]
692304	13	31.79	11.90	-19.89
607494	14	23.14	11.44	-11.70
912525	17	19.36	10.12	- 9.24
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
947851	45	28.33	2.11	-26.22
Mean[6]	29	26.68	5.71	-20.96
S.D.[7]	12	4.68	3.36	5.97

[1] *Number of students* The total number of students included in the report is given first.

[2] *AFSN.* The identification number of each participating student is listed.

[3] *# of sets.* The total number of problem sets taken by each student appears.

[4] *Mean set latency (first-last).* The mean response latency is given for the first and last problem sets for each student.

[5] *Change.* The figure represents the amount of the decrease in mean response latency from the first to the last problem set for the individual.

[6] *Mean.* The columns show the averages of the number of sets, mean set latency (first and last problem sets), and change scores.

[7] *S.D.*. Columns show the standard deviations of the number of sets, mean set latency (first and last problem sets), and change scores.

TABLE 14

Simulated Pacing Model
Management Report

COURSE	BLOCK	LESSON	DATES	REPORT
PME	II	01	08/11/72-08/12/72	02

Number of Students[1]
45

	# of Sets[2]	Mean Set Latency[3] First	Last	Change[4]
Mean	25.51	25.93	6.57	-19.36
S.D.	10.90	4.51	3.49	5.65

[1] *Number of students.* The cumulative total number of students who completed the lesson is shown.

[2] *# of sets.* The column presents the mean and standard deviation of the number of problem sets completed by the students enrolled.

[3] *Mean set latency (first-last).* Included is the mean and standard deviation of the first and last mean problem set latencies.

[4] *Change.* The mean and standard deviation of the latency change from the first to the last problem sets.

TABLE 15

Simulated Pacing Model Cumulative
Management Report

COURSE	BLOCK	LESSON	DATES	REPORT
PME	III	01	08/11/72-09/12/72	02

Number of Students[1]
90

	# of Sets[2]	Mean Set Latency[3] First	Last	Change[4]
Mean	26.12	25.46	6.37	-19.09
S.D.	11.31	4.61	3.43	5.64

[1] *Number of students.* The cumulative total number of students who completed the lesson is shown.

[2] *# of sets.* The column presents the mean and standard deviation of the number of problem sets completed by the students enrolled.

[3] *Mean set latency (first-last).* Included is the mean and standard deviation of the first and last mean problem set latencies.

[4] *Change.* The mean and standard deviation of the latency change from the first to the last problem sets.

IV. MONITORING MODEL FOR ADAPTIVE INSTRUCTION

Adaptive instructional models have different purposes and techniques. The drill-and-practice model described previously, for example, uses preassessment measures and rules to guide the student to mastery after instruction has occurred. The pacing model simulation uses only within-instruction measures to achieve faster performance times without degrading the student's mastery. As the AIS is developed and becomes operational, other models will be defined with similar context-specific rules and goals.

After implementation of AIS instructional materials with such models, it will still be necessary to have techniques for selecting from among these the most probable alternative for student success. It will be necessary to decide when and for whom these models for instruction will be used. The monitoring model provides this capability by relating measures of each student's unique learning attributes to the instructional options and the predicted availability of resources.

The monitoring model has as its primary purpose the selection of instructional treatments via prediction techniques that match characteristics of individual students with training characteristics. Each treatment is composed of media types, instructional topics for content, instructional strategies, and other aspects of the instructional environment which may be relevant in the training process. The model is algorithmic because it uses a set of rules to arrive at the individualized instructional treatment. The algorithmic rules applied in this model were based on multiple linear regression analysis and sequential decision making. Regression techniques attempt to regress scores toward a central point along a line fitted to the scores. Regressing across multiple predictor variables such as prior training, ability scores, personality variables, aptitude tests, and historical variables aids in finding the optimal location on the line. That is, given student scores and task characteristics, the performances and times of several alternative instructional treatments could be predicted for a given student at a given task. It is necessary to have a regression equation, consisting of predictor variables into which particular scores for students are input and from which predictive outcome values can be generated, for each alternative training treatment. Comparing the predictive values produced for each alternative treatment makes it possible to select the best treatment predicted for an individual. In the computer-based environment of AIS, the student could be assigned his treatment directly via an AIS terminal.

Since one of the major tasks for AIM in designing adaptive models was to determine appropriate variables with predictive value and to continuously monitor their effectiveness, the simulation approach demonstrated a technique within the model which categorized the types of variables according to their expected interrelated predictive values and their methodological updating requirements. The predictor values of personality, aptitude, and performance/state variables were separated into three different regression equations for each instructional treatment. In this manner, the utility of each type of predictor measure was updated and evaluated more easily. In addition, within the computer-based environment of AIS, it will be possible to change the predictor variables within a given type (*e.g.*, personality, aptitude, or performance/state) and to update the values of the equations as more data are acquired on the students trained by AIS.

Data Elements

In this section the variables required for input and output are identified and defined. Input variables are categorized as preassessment data (measures of the student or task taken prior to lesson participation for use in the prediction) and macro-performance data (measures of student performance and time taken from lesson participation) which may be used to modify the learner's behavior through incentives or updating of predictors. Output variables are discussed within the context of the inputs for both preassessment and macro-performance data, since the outputs are the purpose of the inputs and are not independent.

Preassessment data. The monitoring model simulation used regression equations with predictor categories consisting of aptitude, personality, and performance/state variables to select instructional treatments. The goal was to predict the best performance for a given student on a given task with alternative instructional treatments. It was necessary to have a regression equation for each type of treatment into which particular values for students could be input, and from which a predicted outcome could be generated. Comparison of the statistical values for each treatment permitted selection of the best predicted treatment for an individual. From the initial regression weights and the corresponding student data, the estimated time and performance scores for each student were computed. In addition, these regression coefficients were assumed to be updated periodically as more data were collected on the students. For purposes of this simulation, the beta weights and student data were generated utilizing correlation matrices for all of the predictor variables. The predictor variables selected for feasibility and simulation were grouped into three categories.

Group 1, aptitude variables, were basic capabilities that the student brought to the course. Hence, aptitude variables exemplified measures which would likely have valuable predictive power with student adaptive instructional treatments. Four of the variables chosen were from tests taken by Air Force enlistees (ASVAB word test and arithmetic reasoning test, AQE electronics aptitude test and AFQT). A fifth variable, task index, was a measure specifically related to the behavior involved in the performance of AIS lessons. The task index ranged from a low score, reflecting abstract, symbolic though, to high scores reflecting psychomotor performance tasks. The task index reflected the close relationship of task requirements with media features of the treatment.

Group 2, personality variables, consisted of five personality measures assumed to have validity for Air Force students enrolled in the PME course. The first, need achievement, was an estimation of the student's motivation or drive. The second, trait anxiety, was a measure of a consistent level of anxiety over a period of time as opposed to momentary anxiety caused by specific situations. The third variable, epistemic curiosity, was a measure of the student's search behavior for further information. The fourth personality variable, media adaptability index, indicated the capability of the student to acquire information by a type of instructional media presentation. The final variable was that of learning style, which indicated the dominant strategies a student used in a learning task.

Group 3, performance/state variables, were closely related to the macro-measures to be discussed in the next paragraph (score and time on previous lesson, pretest score, state anxiety, and incentive average to date). Performance/state variables were measured just prior to or between lessons, and were updated between lessons. This was unlike the variables of the first two groups which were fixed prior to instruction to a complete block or course.

Macro-performance data. The macro-performance data consisted of measures taken between lessons which were primarily used to arrive at proper incentive and lesson management. In lesson B the incentive units were generated according to an algorithm which provided more incentive units to the student who spent a longer time on the previous lesson than had been targeted. This algorithm was an attempt to motivate the student by telling him he would gain the larger number of incentive units if he went faster during the next lesson. Thus, his time on the previous lesson was the input to this incentive management technique. The output was the number of incentive units to be provided. The algorithm follows:

1. If a student took between zero and five minutes over the predicted time for lesson A, he would acquire a multiple of two times the number of standard units for lesson B.

2. If a student took from five to ten minutes over the predicted time for lesson A, he would achieve a multiple of four times the standard incentive units for lesson B.

3. If a student spent more than ten minutes he would achieve a multiple of six incentive units over the standard number for lesson B.

Simulation structure. The monitoring model, using regression techniques, has been selected as an overall monitor model for the adaptive models of AIS. A function of the model is to maintain control on available resources. Another functional mode is the collection of lesson performance and time data for student prescription. This could also be used in evaluation, both formative and summative. In effect, the model's goal is training time reduction by analysis, prediction, and selection of mastery-oriented instructional tasks. The role of the monitoring model is to insure that cost effectiveness and training time reduction are realized.

Major Components of the Monitoring Model Simulation

The general components of the multistage monitoring model are discussed in three stages: (a) analysis, (b) prediction and monitoring, and (c) evaluation and update. The analysis stage was a time period in which the initial measures for predictor variables were chosen on the basis of the empirical literature. Measures on trainees at Lowry Air Force Base produced data for analysis in regression equations to determine the most appropriate combination of predictors for use within the computer-based model during real-time training (Figure 5).

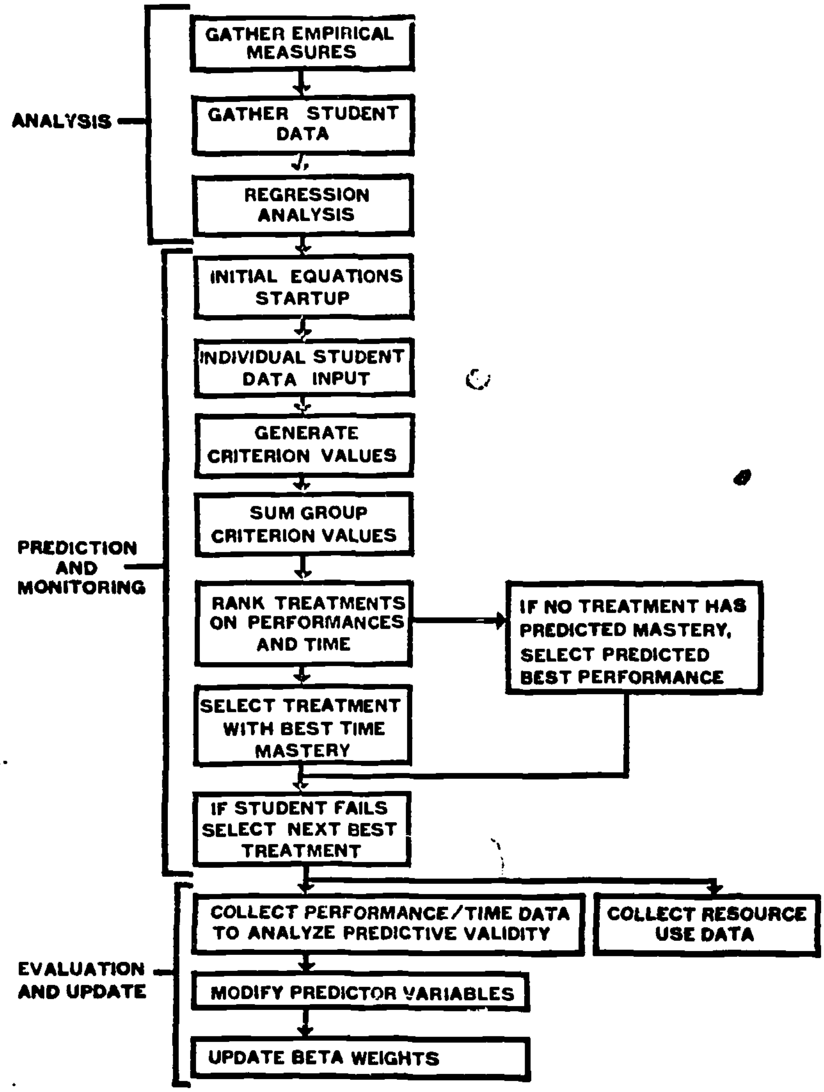


Figure 5.--Functional flow of the Monitoring Model

The second stage, prediction and monitoring, began with these equations and predictor variables. As each student proceeded through lessons, his assessment measures and instructional history measures were input to these equations along with the existing beta coefficients of the previously determined equations. Criterion values by which to select treatments were generated from the equations by predictor-type groups for both performance and time and for each alternative. The groups' criterion values in the model would be summed for both performance values and time values. The next step was to select the treatment on the basis of these rankings. If no treatment had a predicted mastery, the one with the best predicted performance was selected. If the student failed this selected treatment, the next best treatment was chosen. If the student failed all selected treatments, the instructor was notified. For evaluation and updating of the equations and measures, the data for student performance and time were recorded and blocked according to the treatment chosen and student characteristics. In this way, both the decision rule for selection of a treatment and the treatment's effectiveness were evaluated. If the treatment was not used or was used ineffectively, it was modified or deleted from the instructional environment.

Instructional context. The instructional context for the monitoring simulation was Block IV of the Precision Measuring Equipment course, titled, "Vacuum Tubes and Solid State Principles and Power Supplies." Unit 1, Electron Tube Theory, targeted for twelve hours of conventional instruction, was specifically chosen for the simulation. This unit was modified to contain five lessons. The best treatment within each lesson for any given student was predicted. It was necessary to define possible treatments within each lesson according to what seemed reasonable in terms of content and behavioral objectives as stated in the Air Force Plan of Instruction. The time and performance criterion values were generated for each of the following:

Lesson A. Electron Emission (1 hour)

1. Text and workbook
2. PI text and workbook
3. Film loop and workbook
4. Television
5. CAI tutorial

Lesson B. Tube Filaments (2 hours)

1. Text and workbook
2. PI and text and workbook
3. Film loop and workbook
4. Television
5. CAI tutorial

Lesson C. Diode Tubes (6 hours)

1. PI Text
2. Programmed slide tape presentation and workbook
3. PI text and computer-based tutorial with drill and practice
4. Text, film, and workbook
5. Film, workbook, and computer-based tutorial and drill and practice

Lesson D. Tube Tester Usage (1 hour)

1. Concept film, study guide (redundancy level 1), and workbench
2. Concept film, study guide (redundancy level 2), and workbench
3. Concept film, study guide (redundancy level 3), and workbench
4. Instructor demonstration, study guide (redundancy level 1), and workbench
5. Instructor demonstration, study guide (redundancy level 2), and workbench
6. Instructor demonstration, study guide (redundancy level 3), and workbench

Lesson E. Gas Diodes (2 hours)

1. Slide tape, workbook, and workbench
2. Student guide, workbook, and workbench
3. Videotaped lecture, workbook, and workbench
4. CAI tutorial, workbook, and workbench
5. PI text, workbook workbench

Each of the five simulated lessons had five or more instructional alternatives (more alternatives could be handled within the model). A total of 26 instructional treatments were considered in the simulation, and regression equations were generated for each alternative treatment. For all lessons a best treatment was selected maximizing performance with a minimum time.

Incentives. The simulation illustrated the use of incentive management techniques throughout all lessons. The student was provided with incentive units (tokens) which could be used to "buy" desired outcomes such as time off base, higher pay and promotion. The simulation used an arbitrary time generated by the prediction of time as the expected average for completion by a student. For each one minute he gained, an incentive unit was given to the student. At the end of each lesson, the student was told the number of incentive units he gained or lost. These arbitrary formulas will be replaced in the operational AIS by empirical determination.

Output Reports

Three reports were designed for the monitoring model simulation. Three sample reports from the simulation will be presented and discussed. They are:

1. The Report to the Student
2. The Report to the Instructor
3. The Management Report

The report to the student. Each simulated student received a report before he began each lesson, and after completion of the lesson. Table 16 shows that complete identification of the student, course, and date were printed out prior to the assignment of instruction. Following completion of the lesson, all identification information was once again printed out for the student, plus the "after lesson" report as shown in Table 17.

If the student in Table 17 had not reached mastery, his message would have read: "You have received a 78% score for lesson A, Electron Emission. This is failing. You seem to be having trouble with this material. It is suggested that the following people in your class may be able to help.

Creamer, U.R.
Yaeger, P.H.
Paul, T.H.
Trotman, R.S."

Report to the instructor. For all students currently finishing lessons, the instructor received a report on the lesson containing the information simulated in Table 18. The report contained a summary, a section on students failing to reach mastery, and individual records.

The management report. The management report demonstrated the overall monitoring capability of the model. Management reports were generated per lesson, and were divided by instructor and student population per instructor. The assumption was that this report would go to a manager who had a number of instructors under his supervision. Table 19 is a simulated management report section for one instructor only; the actual report would be composed of sections for a number of instructors.

The management report was the final, and most comprehensive, report simulated for the monitoring model. A commentary on validation of the model concludes this section.

TABLE 16

Simulated Monitoring Report to the Student (Before Lesson)

AFSN	NAME	COURSE	BLOCK	LESSON	INSTRUCTOR	DATE
224726	Frost,CP	PME	IV	A	Huyt, RE	10/22/72

Your assignment is .....

First you should sign on to a computer terminal and read lesson 5. This will help you improve your reading speed. Next read Chapter 6 on electron emission in the electronics textbook TB 371. Finally, do exercises 1-7 in workbook WB 3ABR32420-17.[1]
Estimated time for this assignment is 1 hour.[2]
You may receive 1 incentive unit for each minute saved in addition to 5 incentive units for receiving a score of 80% or better.[3]

[1]The name of the assignment and its resource location.

[2]The estimated training time.

[3]The number of incentive units obtainable.

TABLE 17

Simulated Monitoring Report to the Student (After Lesson)

AFSN	NAME	COURSE	BLOCK	LESSON	INSTRUCTOR	DATE
224726	Frost,CP	PME	IV	A	Huyt, RE	10/22/72

You have achieved a score of 91% mastery for lesson A, Electron Emission. This is passing and merits 5 incentive units. Your assignment was completed in 31 minutes, a gain of 29 minutes, which merits a total of 34 incentive units. Incentive units earned may be applied to any of the incentive items on the list passed out to you for this course.

TABLE 18

Simulated Monitoring Report
to the Instructor

INSTRUCTOR	COURSE	BLOCK	LESSON	DATE
Huyt, R.E.	PME	IV	A	10/27/72

Summary [1]

Students passing = 14   Average Mastery Score = 84   Range = 80 to 92

Students Who Failed to Reach Mastery on First Try [2]

Name	AFSN	Average Score	Average Time
Danner, D.E.	323237	78	38'

Student Individual Records [3]

AFSN	Treatment Assigned	Rank Order	Mastery Score Predicted/Obtained	Time Predicted/Obt.	Incentives Gained
873586	1	1	91/88	54/38	27
780538	1	1	84/81	48/50	15
220550	1	1	86/82	50/70	5
935596	1	1	88/92	51/48	17
423998	1	1	85/81	49/64	5
323237	4	1	81/78	64/38	0
323238	1	2	84/80	47/48	17
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
417767	4	1	81/84	45/31	34

[1] *Summary.* This section of the instructor report presented the number of students passing, the average score, the score range, and the average time (minutes).

[2] *Students Who Failed to Reach Mastery on First Try.* These students, listed by name and AFSN, with average score and time are shown in the student individual records as repeating the lesson via a different treatment (see AFSN 323237).

[3] *Student Individual Records.* Six columns of information identified the student by AFSN, gave the number of the simulated treatment prescribed followed by the rank order of that particular prescription, mastery score predicted and obtained, time predicted and obtained, and incentives gained. All treatments prescribed, whether available or not, were listed in the simulation.

TABLE 19

Simulated Monitoring Model Management Report

COURSE	BLOCK	LESSON	DATE
PME	IV	08	10/27/72

Instructor = Huyt, R.E. Shift = 1

Number of students = 15
Students Passing = 14 Average Mastery Score = 88 (Range 81 to 95)
Students Failing = 1 Average Mastery Score = 71 (Range 71 to 71)

Treatment Selection[1]

Treatment	Percent of Total Prescribed	Actual Number Prescribed
1	0%	0
2	25%	4
3	0%	0
4	69%	11
5	6%	1

Treatment Unavailability[2]

Treatment	Percent Unavailable of Selections	Actual No. Unavailable of Selections	No. "Down" of Selections	No "In Use" of Selections
1	0%	0	0	0
2	43%	3	3	0
3	0%	0	0	0
4	0%	0	0	0
5	0%	0	0	0

Treatment Mastery Summary[3]

Treatment	Percent Mastery Reached on Treatment	Incentive Gains on Treatment
1	0%	0
2	100%	144
3	0%	0
4	91%	395
5	100%	49

Total Incentives Given[4]

This unit = 588
Average Incentives Given = 39

[1] *Treatment Selection.* For each of the treatments available for prescription, the percent of prescription was given (*i.e.*, 25 percent of all students received prescriptions for treatment 2). The actual number of students receiving the prescription was also printed out.

[2] *Treatment Unavailability.* For each treatment, the percent and actual number of selections unavailable were noted, and the reasons for unavailability ("down" or "in use") completed the information on treatment availability.

[3] *Treatment Mastery Summary.* This information gave the percent of the time that each treatment produced mastery (*i.e.*, treatment 4 produced mastery 91 percent of the times it was prescribed). The summary also presented incentive gains for each treatment.

[4] *Total Incentives Given.* Incentive information was in two parts: a total of incentives given to all students on this unit, and an average number of incentives given per student for this unit.

Validation and Future Refinements

In terms of future extensions, the most important validation approach would be to differentially weigh the sets of equations according to the cognitive, personality, and on-task sets of variables. These new functional relationships would provide a better fit between the predicted and observed values for given students. Other variations, such as the inclusion of new variables, new instructional treatments, and new resource arrangements, should improve the efficacy of the model in terms of its monitoring and managing capability. These are pathways to be pursued.

Students' predicted and observed performance and time values should given a direct daily estimate as to the efficacy of the model. The establishment of appropriate beta weight estimates will require a large set (sample size in excess of 300) of students who will pass through the material without adaptation. As different conditions, such as material updates or modification are introduced, the findings will have to be updated to be relfected in each of the beta weights. As these periodic update values converge, one can be more confident that the model is working appropriately.

V. CONCLUSION

The previous three sections of this report provided detailed descriptions of the computer simulation of three adaptive instructional models - drill-and-practice, pacing, and monitoring. Several steps were followed in the discussion of each model. First, there was a brief introduction to the purpose of the model. Next, data elements were specified. For each type of data needed, specific examples (AQE, AFQT, ASVAB scores) were used by the simulation to illustrate their roles within the model. Other measures should also be considered to fulfill these roles. (Similarly, the reports described in the previous sections suggested the types of information which can be generated by the models, but may be modified according to needs.) The third step was to flowchart the major components of each model. This provided an organizer for both the development and discussion of the models. The quantitative processes of the models as well as the mathematical functions used to generate student data for the simulations were discussed in this section. Finally, sample output reports were provided with annotated explanations of their content. Each model provided reports for the student, the instructor, and the management personnel. These reports suggested the types of information which can be generated by the AIM models.

A major purpose of developing the simulations was to concretize the models developed in Phase I of the AIM contract. The contrast of details between the Phase I report which discussed the models in general, and the more detailed simulations described in this report, are highly visible. First, precise data needs were clarified. The operational processes were detailed, resulting in the computer programs documented in another report (McMurchie, Bennison, & Tam, 1973). Similarly, the possible output from each of the models was identified in detail. Furthermore, during the process of developing the simulations, flows and omissions in the original model designs were noted and corrected accordingly.

Another outcome of the simulations was the identification of additional research which needs to be done in order to fully implement the models. First, the most appropriate measures to fulfill the input data needs of the models must be determined. Research is needed to investigate model parameters such as the optimum block size for the drill-and-practice models. In addition, the monitoring model requires an extensive data collection phase prior to its actual implementation. A large number of students should be randomly assigned to the available treatments to empirically derive the initial beta weights for the regression equations. Each of the preceding three sections concluded with suggestions for future validation and model refinement.

The development of Adaptive Instructional Models (AIM) is a major step toward the realization of the Air Force's planned Advanced Instructional System (AIS). The AIMs hold the most promise for achieving the AIS goals of reducing training time without sacrificing performance levels. The simulation of the models proved to be a profitable step toward their implementation. It is, therefore, recommended that the same procedure be repeated with the other models described in the Phase I report, specifically the concept acquisition, rule learning, and problem-solving models.

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