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A STUDY IN PROGRAMMED INSTRUCTION USING
THE MEDIUM OF VIDEO TAPE

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By

Harry Kent Moore, B.S., Ed.M., M.S.

*** *** ***

The Ohio State University
1972

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ACKNOWLEDGMENTS

I feel a particular gratitude to all three members of my dissertation reading committee each of whom has provided needed encouragement at one critical time or another in the course of my work at Ohio State: to Professor Wave H. Shaffer for his continual encouragement and help starting with my early days on the Ohio State campus; to Professor John B. Hough, for contributing much in the way of thoughtful suggestions toward the organization and content of the dissertation writing; and to Professor I. Keith Tyler, who as advisor, was able to offer those comments of criticism that added immeasurably toward improving the final product while at the same time leaving my self confidence intact.

The facilities and materials needed for the production and presentation of the video taped lessons were provided by the Instructional Media Center of Madison College under the direction of Richard Garlick. A sincere thank you is owed for his cooperation and for the competent work of the graphic artists and studio crew.

Professor John C. Wells, as chairman of my department at Madison College, was most helpful in facilitating much of the work of the study.

Finally, a special appreciation is felt to Helen, my wife, and children, Andrew, Scott and Elise, for their willing patience over the past few years in seeing this study completed.
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CHAPTER I

INTRODUCTION

Instructional television and programmed instruction have both made a distinct impact in education over the past decade but with relatively little interaction between these two forms.

Teaching by television has been largely a matter of placing the tools and environment of the conventional classroom before the studio camera and from there transmitting the seen, but unseeing, image of the teacher by the electronic intermediary to the viewing learners.

Programmed instruction, associated primarily with the teaching machine in the late 1950's, eventually was adapted to other media, with perhaps the printed manual making the greatest inroads. Markle's definition will serve as a useful point of reference:

We define an instructional program as a reproducible sequence of instructional events designed to produce a measurable and consistent effect on the behavior of each and every consistent student. . . . Such a definition specifies neither the medium of presentation nor the theoretical psychological principles of governing program construction.

By the above criteria, no medium nor mode of pacing is proscribed from the array of possibilities that may be used in the programmed instruction context.

The two chief modes of pacing may be contrasted. Self pacing occurs when the learner is the chief determiner of the time spent on each instructional event while with external pacing the decision on time allowance is made by someone other than the individual learner.

Programmed instruction has been adapted to various types of media, which include the teaching machine, the printed manual, the filmstrip, audio tape, the computer and video tape. Of these, all but the last may lend themselves to learner self pacing.

However, the media suitable to self pacing are limited in terms of the type of visual and aural cues that may be used. Video-tape, not readily adapted to self pacing, on the other hand can provide certain types of these cues unavailable in the other media.

The advantages of self pacing may have been too much emphasized and it may in fact be this very aspect which tends to discourage its adoption:

Some publisher's manuals say that the differences in student performance are an advantage; they enable the teacher to work with the individual students. This is a naive view since it is doubtful that any teacher is continually going to go from student to student answering the same question and providing the same instruction and advice.\(^2\)

Gropper and Kress\(^3\) suggest that self pacing is, in many instances, an inefficient and ineffective form of instruction.

---


Television teaching, on the other hand, has adopted much of the "show business" aura, frequently with little or no thought given to what transpires in the mind of the passive learner.

A premise of the study described here is that a fruitful wedding of the television medium with the active responding afforded by programmed instruction does have as yet untapped possibilities that deserve further study.

Whether television proves useful in this service (use of programmed instruction) or not, the discipline of programmed instruction design and conscientious application of other areas of research would introduce a healthy element to the field of instructional broadcasting and possibly destroy some of the conventions which now bind us to the show format.4

The above statement would seem to apply equally well to closed circuit television usage as to broadcasting.

Developments in the video taping field have made the prospect of such a synthesis all the more real by facilitating the reproducibility aspect of programmed instruction. The financial and technical requirements needed to acquire and operate such equipment are readily within the reach of most educational institutions today.

The technical feasibility of adapting programmed instruction to video tape have been demonstrated, two instances being a series of lessons on Chemical Bonding5 and College English grammar.6


Even with the feasibility of such a union established, a critical question that must yet be considered is the matter of pacing; it is presumed that the mode will be externally determined. The possibility of self pacing in this context is admitted but would seem not practical considering the present state of the art in equipment design.

A mere straightforward adaptation of one instruction form to a given medium without a prior understanding of certain relevant variables such as learner aptitudes and content nature as well as the pacing could be disastrous to such an enterprise.

Carroll's\textsuperscript{7} model, which proposes that the success of any learning process is, in part, a function of time needed by the learner to complete a given task and actual time available, serves as a useful reference frame. Learning is incomplete to the extent that time available is less than time needed. Factors which determine time needed are (1) learner aptitudes, (2) learner ability to comprehend instruction and (3) quality of instruction.

The study described in these pages is the result of efforts to isolate two of the above factors as independent variables, namely (1) time available and (2) learner aptitudes. Video tape serves as the medium of instruction.

Definition of Terms

Programmed Instruction.—Method by which instructional content is presented to the learner in a systematic and reproducible step-by-step fashion. The content area is broken up into discrete units or ideas each of which is presented as a frame. Subsequent to the frame presentation, the learner is asked to respond, either overtly or covertly, to some question or task that represents a relevant part of that frame. Knowledge of results, or correctness of learner's answer, is generally given after the learner response.

Program Frame.—Unit of instruction containing information of either verbal or non-verbal nature or a combination of both; this may involve a phrase, sentence, paragraph, multi-paragraph expositions or visual elements such as diagrams, tables, pictures, demonstrations, etc. Each frame will generally be followed by a relevant question or task requiring a learner response.\(^8\)

Program Strategy.—Determination of such aspects of the program as whether program is linear or branching, type of pacing, type of learner response expected, frame repetition, information per frame, etc.

Self Paced Programmed Instruction.—Time allotted to each program frame is determined by the individual learner.

Externally Paced Programmed Instruction.—Time allotted to each program frame is determined by some external agent or condition and is the same for all learners in a given group. A fast pace implies a minimum time interval per frame, a slow pace, a more than adequate time allowance.

Learner Aptitude.--Variable determined from I.Q. or aptitude test or other similar criterion.

Learning Effectiveness.--Measure of content learned as determined from posttest scores.

Learning Performance.--Measure of lack of errors made by learner in responding to program frames.

Time Needed for Instruction.--Minimum time needed by learner to attain learning objectives, given the particular quality of instruction and the learner's aptitude. This is an inferred quantity and cannot be measured directly in most instances.

Learning Efficiency.--Applicable when time allowed for learning exceeds time needed. As with the latter, efficiency cannot be directly measured. An inefficient program is inferred when time allowed greatly exceeds that needed.
CHAPTER II

LITERATURE SURVEY

A number of programmed learning studies are reported in which time of instruction, learner aptitude or both are treated as two important variables examined along with learning effectiveness and performance. These investigations tend to fall into one or a combination of the following categories:

1. Studies where time of instruction is a dependent variable in a self pacing context.

2. Studies where time of instruction or program strategy is a manipulatable variable in the externally paced instructional context.

3. Studies where externally paced instruction is compared to self paced instruction.

4. Studies that take into account the student aptitude variable as it interacts with time of instruction and/or program strategy.

Carpenter and Greenhill have reported doing a series of four studies all related to the question of pacing and programmed instruction. In the first of these, no difference was found in the learning effectiveness using college algebra content when subjects were self paced by either teaching machine or programmed text or were externally paced by filmstrips.

9Carpenter and Greenhill, op. cit.
In a second study they found no difference in learning of college algebra when the externally paced rate with filmstrip was set at 80%, 90%, 100% and 110% of a base rate, this latter being the mean rate taken by a sample group working in a self paced program.

A third experiment compared learning effectiveness in college algebra between self paced teaching machine instruction and externally paced closed circuit television instruction; again the results showed equivalent gains for both methods.

The fourth Carpenter and Greenhill study used college English grammar content to compare three forms of instruction: (1) externally paced by closed circuit television, (2) self paced by teaching machine and (3) lecture-discussion led by an experienced instructor. "No substantial differences" in student learning was revealed among the three methods although an attitude measure favored the lecture-discussion.

Frye\(^{10}\) compared time spent per pupil in external pacing to that in self pacing using selected topics from algebra with filmstrip projectors. The external pace rate was determined by the time interval required for all learners to complete a given frame. Subjects were classified according to a composite score of Primary Mental Abilities and Orleans Algebra Prognosis test scores. It was found that an externally paced heterogeneous group, taken from first and fourth quartiles, will spend significantly more time completing a program than will an externally paced homogeneous group, taken from second and third

quartiles, or than self paced groups that are either homogeneous or heterogeneous. This finding would support the contention that group external pacing is most efficiently undertaken with a homogeneous group. Such a result, it should be remembered, is very closely tied to the mode of external pacing.

Janin\textsuperscript{11} with an experimental group externally paced 27 frames on content in learning of a foreign language alphabet, allowing 90 seconds per frame for a total time of 45 minutes. This group performed significantly higher on a posttest than another group who were self paced on the same program where average time to completion was one hour and 42 minutes.

A study done by Feldhusen and Bir\textsuperscript{12} compared learning results in General Psychology using nine different methods of programmed instruction, among these being an externally paced strategy. This latter was determined at least as effective as any of the other methods.

Gropper and Kress\textsuperscript{13} conducted a series of three experiments pertinent to the question of pacing using science content with eighth grade subjects. In the first of these, learner achievement and program error rate were observed as a function of IQ, reading ability, pretest scores and, most importantly, self paced rate adopted by the learner.


\textsuperscript{13}Gropper and Kress, \textit{op. cit.}
The chief result of this part of the study was that both learning performance and effectiveness were shown to have suffered with the combination of low IQ and a fast self adopted pace.

In a second experiment, error rates and posttest achievement were compared among learners using self paced booklets and those operating at three different rates (fast, medium, slow) of external pacing using slide film. The actual criteria for what constituted a fast or slow pace was not specified in the journal report. As expected, a faster externally imposed tempo was accompanied by a higher error rate; however, a comparable difference was not observed in posttest achievement. The self paced students adopted a rate that was similar to the fast external tempo; this group did not, however, score as high on posttest achievement as the slow fixed pace group.

The third Gropper and Kress study in this series sought to determine the effect of prompting strength and external pace tempo on error rates and achievement, television being the medium of instruction. Increased prompting reduced the number of performance errors but, surprisingly perhaps, was negatively correlated with posttest achievement. As in the second study, increased tempo led to more performance errors. The learners in this study had earlier been characterized as fast or slow, as determined from observations made on the same group in self pacing instruction. In the analysis of results, IQ was held constant, showing that fast learners did better than slow learners both in error rate and posttest achievement in the fast externally paced mode. With IQ constant in the externally slow pace condition, fast learners did less well than slow learners on both criterion measures.
Kress\textsuperscript{14} conducted a follow-up to the above described series, using sixth grade students in one study which then was replicated with twelfth graders. Content and medium was material from the physical sciences and programmed booklets. A $2 \times 2 \times 2$ factorial design was used in which subjects were categorized according to IQ groups (high or low), pacing mode (self paced or externally paced) and administrative setting (subjects working either in groups or in isolation). Administrative setting was shown to be important on two criteria; students working in isolation did significantly less well on program performance and in the self paced mode took less time to complete the program. The IQ score was shown to significantly vary with the three criteria, (1) program performance, (2) immediate post-test score and (3) delayed posttest score; in the twelfth grade study only IQ significantly influenced time to complete the program, the higher group requiring less time. The self pacing mode was shown to be significantly favored in program performance for both age studies as well as on delayed posttest retention in the twelfth grade group; in all other posttest measures for both age groups, the self paced subjects showed higher mean scores, but not at a significant level. Such a result, curiously, was contrary to the previous findings of Gropper and Kress.

One significant interaction was observed, this being in the twelfth grade group; high IQ students in the self paced mode did

\textsuperscript{14}Gerard C. Kress, Jr., The Effects of Pacing on Programmed Learning Under Several Administrative Conditions (American Institutes for Research, 1966).

\textsuperscript{15}Gropper and Kress, op. cit.
significantly better on program performance than did those in the externally paced mode, a difference not seen among the low IQ groups. A note should be made on one aspect of the methodology used in Kress' study; from the self paced groups, for which instruction was conducted first, he established optimal learning times for each IQ group; these accordingly were the basis for determining pace rates. Low IQ groups thus were afforded more time in the external pace mode. Kress also noted the correlation between achievement on posttests and time to complete program for the self paced groups. The sixth grade subjects showed virtually no relation (-.03 and -.04, time with immediate and delayed posttests) in contrast to those in the twelfth grade (-.38 and -.31, time with immediate and delayed posttests). This led to the investigator's suggestion that the maturer student is more likely to operate in the self pacing mode at a rate compatible with aptitude.

Crist* examined external pacing using a somewhat different method. All members of the learning group simultaneously view a frame projected on a screen; one member of the group is chosen by random selection to respond orally to that frame. In this manner the group pace rate for a given frame is determined by the time needed by that one individual. In these studies which compared this type of group method to self pacing, no consistent differences were found in learning achievement.

* Crist, op. cit.
Alter and Silverman\textsuperscript{17} ran a 2 x 2 factorial design study with college students serving as subjects learning content in basic electricity. The two factors examined were pacing mode (self vs. external) and response mode (overt vs. covert). Teaching machines were used and in the external pace mode were timed to advance automatically at 20 seconds per frame for one part of the lesson segment and 35 seconds for another. No significant $F$ ratio for main effects or interaction was found although the externally paced group was slightly favored.

Gallegos\textsuperscript{18} compared high IQ students to low IQ at fast and slow externally paced programs in a Spanish Writing course. Mean self paced rate for high and low ability learners were the basis for determining the fast (high IQ) and slow (low IQ) external pace rates. Seventy-two frames were presented on a teaching machine in the fast and slow times of 22 and 45 minutes, respectively. Additionally, high and low IQ groups were also instructed in the same program in a self paced mode. No difference was found in posttest achievement between high and low IQ learners at the slow external pace; however, at the fast pace, the high IQ learners were favored. The self paced mode was significantly superior to the fast external pace for both high and low IQ groups. However, this advantage was not evident when self pace was contrasted to the slow external pace. Though an interaction effect trend was


evident between pace and aptitude, it was not statistically significant in the two-way analysis of variance.

Eckhardt\(^1\) varied the rate of programmed instruction presented on movie-filmstrip-audio tape combination by electronically compressing the speech on the tape. A 3 x 2 factorial design grouped subjects, who were Air Force recruits, into three rate treatments (150, 210 and 275 words-per-minute) and into high or low aptitude groups based on the Armed Forces Qualification Test; content was a 45-question frame program of Traffic Accident Patterns. One hour was required for the 150 words-per-minute treatment. The results conformed closely to those of the Gallegos study where it was shown that the low aptitude group was most likely to suffer in posttest achievement with the faster pace. On program performance (response scores) only aptitude was shown to be a significant factor.

The Eckhardt study above is related to another area of research not directly involving programmed instruction, but nevertheless related to the question of external pacing; namely, investigations in speech compression. Studies by Foulke\(^2\) indicate that a faster words-per-minute reading rate of a passage is accompanied by less comprehension on the part of the listener. He observed that comprehension declines markedly as the rate exceeds 275 words-per-minute.

\(^1\)Wymond Walter Eckhardt, Jr., "Learning in Multimedia Programmed Instruction as a Function of Aptitude and Instruction Rate Controlled by Compressed Speech" (unpublished Doctoral dissertation, 1969).

\(^2\)Emerson Foulke, Proceeding of the Louisville Conference on Time Compressed Speech (Louisville: Center for Rate Controlled Recording, University of Louisville, 1967), p. 19.
Literature Survey Summary

Certain generalizations seem apparent from an analysis of the studies reported.

First, comparative results tend to suggest that in the particular contexts reported, programmed instruction in the externally paced mode was at least as or more effective as self pacing, Kress' study being an exception.

Second, learners in a self paced mode do not necessarily adopt a pace that is most efficient or effective. High ability learners are apt to go slower than necessary, hence inefficiently. Low ability learners are apt to go faster than desirable, hence ineffectively.

Third, when pace rate is varied in the externally controlled mode, the program is found less effective for the version with less time available to the learner.

Fourth, in an externally paced mode it is the low aptitude learner who is most likely to suffer from the standpoint of both learning performance and effectiveness when a particularly fast pace is imposed. The high ability learner generally appears capable of adapting to an externally fixed pace whether fast or slow. Thus, it follows that externally paced learning will be found effective for a larger proportion of learners if set at a slower rate. The graph of Figure 1 will be helpful in summarizing this principle.

21Kress, op. cit.
Fig. 1.—Relation between learning criteria (effectiveness or performance) and learner aptitude when same programmed content lesson is presented at two different pace rates.

Such a model of interaction between pace rate and aptitude is directly inferred from the Gallegos and Eckhardt studies. The results of Gropper and Kress also appear to lend support.

Finally, a group of the investigations described in the preceding pages, Gropper and Kress, Kress, Gallegos, Eckhardt and Frye, consider the effect of an aptitude variable. Of these five, all but the latter have relied solely upon some measure of general aptitude. Evans expresses need for taking into account the learner's specific aptitudes. "Broadly stated, a high IQ child who cannot read will fail a program assuming reading knowledge, while a less bright reader may do very well on the same program."22 He suggests that knowledge of specific learner aptitudes is important to the design of a successful program strategy.

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The results, summarized above, suggest questions which require further research to be answered. In particular, two seem to invite special consideration: (1) Are the results as exemplified by the model of Figure I generalizable to other contexts using various media and learning content? and (2) Will such interaction occur when aptitudes specific to the content learned are applied?

Three Added Studies

The study as originally conceived was motivated as an outgrowth of the research reported in the preceding section. Added here are the following three references which are related and lend themselves to the interpretation of certain results from the study that were not anticipated prior to the collection of the data.

Shay examined the relation between intelligence and step size in a self-paced program using the criteria of (1) error rate (program performance), (2) posttest measures (program effectiveness) and (3) completion time of program. Intelligence was significantly related to all three of these variables. Step size did influence error rate as well as show interaction with intelligence on this same criterion, i.e., the greater the intelligence, the less handicap observed at a larger step size on the error rate. Step size effect, on the other hand, was not apparent with the posttest measure.

Green used the independent variable, program density, defined as the ratio of number of different responses expected of the learner.

to the total responses required. Thus, a program that called for many repetitions of the same responses would have a low density. It was observed that a higher density was accompanied by a higher error rate (p < .005 level). Green also noted that the particular errors made on the program response were not consistently related to those made by learners on the posttest instrument although there was a significant correlation between program performance and posttest scores. These two results taken together, i.e., little correspondence between program lesson error with posttest error and yet significant correlation between the overall scores on the two criteria, suggest a seeming paradox. A reasonable interpretation of this latter correlation is that learner intelligence, and not program strategy, is the predominant factor in determining both scores. Green does not provide the correlational data that could be used to support this.

The results of the studies of both Shay and of Green seem to have a common thread; namely, that those independent variables associated with the program strategy which are instrumental in determining program response performance (or error rate) are somewhat less influential on posttest measures.

Green also reports on studies involving the effect of program content difficulty and learner ability on program error rate. It was noted that (1) when the program is more difficult or (2) when learners are less able, then the mean error scores are larger and also the variance in error scores is larger.

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25Ibid., p. 170.
Another learning study that deals with external pacing effects and considers the influence of post instruction time intervals is that of Foulke. This investigator observed the retention that blind subjects demonstrate from an audio tape lesson on word comprehension after 0, 7 and 30 days using various word-per-minute rates with different learner groups. The slower paced subjects were superior at all points of time, however, the greatest difference in retention between groups was on the Immediate posttest, or zero day point, and then was observed to be somewhat less after 7 days and essentially negligible at the 30-day point. He notes in his report that the 30-day scores are very close to what subjects might obtain by chance on the multiple choice instrument which was used, and therefore was led to the inference that much of the sameness in group means, regardless of pace, after the 30-day interval is attributed to virtually all the content being forgotten by the subjects.

The first two of the above cited studies did not deal explicitly with external pacing. However the variables, step size and program density, do seem to have characteristics that are comparable to the external pace rate variable in terms of the demands that are made upon the learner. The extent to which this parallel may be carried yet is a matter of conjecture.

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CHAPTER III

BACKGROUND, STUDY MODEL AND HYPOTHESES

Background

The prospect of adapting programmed instruction to the media of video tape as a form of instructional technology has provided the motivation for the study. Success in an innovative endeavor of this type is enhanced when it can be preceded by developmental efforts which provide a working paradigm, in other words, a generalizable framework that may be applied in a large number of settings. It is toward this end that the relationship between pace rate and learner aptitude will be further examined. Such a relationship, if shown to hold in a variety of similar instructional contexts, then may very well serve as a foundation for the sought after model.

The primary objective of this study thus is to provide a partial test for the applicability of this model relationship. In such a test, learner aptitude measures, presumed specific to the particular lesson content area, are to be used.

The Hypothesized Model

Two different perspectives of the model will be examined, first, by looking at the hypothesized relation of learning criterion (performance or effectiveness) as a function strictly of time available for learning and second, by looking at the relation of learning criterion to learner aptitude at four different pace settings.
Variable: Learning Time Available.—The hypothesized influence of time available on learning criterion is illustrated in Figure 2.

![Graph](image.png)

Fig. 2.—Hypothesized influence of variation in externally imposed programmed instruction pace rate on learning criterion (effectiveness or performance).

It is assumed that instructional content is held constant but is presented at varying pace rates to different learner groups chosen randomly from the same population.

A group operating at rate \( a \) or faster would show no appreciable learning whatever, regardless of abilities or quality of instructional content.

The group at \( b \) will show some measurable result on the criterion scores and the group at \( c \) a still substantially larger score.

Point \( d \) represents an optimum or saturation rate. For the particular learner group assumed, no further investment in time beyond this point will yield any further gain on criterion score.

It is not assumed, however, that all learners necessarily have achieved 100 per cent mastery of the criterion at point \( d \). Two
additional factors must be considered: (1) the very probable likelihood that for a given quality of instructional content there are some learners who are incapable of complete mastery regardless of time allowance and (2) the prospect of tedium can very well enter into the process when time available reaches a certain point. It is this latter effect that may tend to depress the criterion score mean beyond point d, suggested by the dashed portion of the curve. For purposes of testing the model, however, primary attention will be focused on points b and c.

Conjecture I. If two learner groups are given pace rates represented by b and c, then the group associated with the latter of these will show a larger set of mean scores on learning criterion.

Variables Learning Time Available and Learner Aptitude.—The above discussion has suggested another aspect to this same model. Figure 3 explicates this, showing a set of four criterion-versus-aptitude curves, each associated with one of the pace reference points. For simplicity, a linear relationship is assumed between criterion score and aptitude.

![Diagram of Learning Effectiveness or Performance vs. Aptitude](image)

Fig. 3.—Hypothesized influence of learner aptitude on learning criterion (effectiveness or performance) at four external pace rates of programmed instruction.
At the hypothesized extreme pace rates, a and d, learner aptitudes would have no influence on criterion scores; this is suggested by the zero line slopes.

At the intermediate rates, learner abilities would enter in and, most importantly, have a greater influence at b than at c. Again the line slope in either case as drawn conveys this difference. The model implies that learners at the slower pace, c, by virtue of being allotted more instructional time, have less dependence upon abilities. It is assumed that such a distinction may be operationally defined in terms of interaction between aptitude and pace rate.

Conjecture II. If two learner groups are given pace rates represented by b and c, then a nonsymmetric interaction (as implied by the corresponding slopes in Figure 3) occurs between pace rate and learner aptitude.

**Study Objective**

The objective of the study is a testing of the two conjectures of the preceding section.

**Null Hypotheses**

1. An increase in learning time will not significantly result in an increase of either of the dependent variables, learning performance and effectiveness.

2. Learner aptitude will have no significant effect on either of the dependent variables, learning performance and effectiveness.

3. There will be no significant interaction between learning time and learner aptitude as they affect either of the dependent variables, learning performance and effectiveness.
4. A variation in the placement of pause intervals within the programmed lesson will not significantly affect either of the dependent variables, learning performance and effectiveness.

**Study Variables**

The hypotheses stated in the preceding section were tested under two contexts using a different lesson content area, (1) verbal or (2) mathematical, in each case.

Dependent variables in either case were (1) response performance scores, (2) immediate posttest scores and (3) delayed posttest scores.

Independent variables were (1) pace rate and (2) aptitude scores.

The Scholastic Aptitude Test (SAT) was the basis for this latter variable. The verbal portion of this score, SAT-V, thus was employed for the verbal content segment of the study and similarly the SAT-M score was used in conjunction with the mathematical portion.
CHAPTER IV

PROCEDURES IN CARRYING OUT THE STUDY

Introduction

The hypotheses and objectives stated at the end of the preceding chapter have served to set the basic context for the conduct of the study. The actual procedures for carrying out the study are detailed in this present chapter. There were four distinct operations involved, each serving as a major topic heading. They are: (1) Lesson Production, (2) Criterion Instrument Development, (3) Instruction and Testing and (4) Analysis of the Data.

Briefly, in preview, the procedure involved developing and producing on video tape at different pace versions two programmed lessons, each representing a distinct content type.

Criterion instruments consisted of program response sheets, completed by subjects during instruction, immediate posttests and a delayed posttest.

Place of the study was Madison College, Harrisonburg, Virginia, with students in the 1972 spring semester course, *Science for Elementary Teachers*. A pilot study was conducted in the 1971 fall semester, in order to try out lesson material, criterion items and perform preliminary data analysis.

Each one of the four major steps in the procedures will next be considered separately.
Lesson Production

Two programmed lesson scripts, each of a distinct content type, were written and produced on video tape in four different pace versions. The two lesson topics were (1) **Insects** and (2) **Simple Machines**. The sequence of events leading up to and including the final video tape lesson production is shown here:

5. Produce final lesson versions on video tape—**Insects**: February, 1972; **Simple Machines**: April, 1972.

The two lesson topics, **Insects** and **Simple Machines**, were selected as being exemplars of content requiring the specific aptitudes involved as subjects in the study, verbal and mathematical, respectively.

**Lesson Content Verbal: Insects.**—The nature of this content lesson calls upon the learner to memorize names and the association of groups, objects and processes. An important premise of the study is that this particular lesson is primarily oriented toward use of the learner's verbal skills and hence, it will be identified as being of a verbal content type. The **Insect** lesson was based on the following outline:

1. Phylum characteristics. Identify:
   a. name of phylum to which insects belong (Arthropoda)
   b. main physical features of Arthropods (exoskeleton, jointed legs)
c. main physical features of insects (three main body parts, three leg pairs)

2. Derivation of insect order names. Translate from Greek the literal meanings of the following:

   a. arthro (jointed)
   b. poda (foot)
   c. arthropoda (jointed leg)
   d. ptera (wing)
   e. ortho (straight)
   f. orthoptera (straight wing)
   g. di (two)
   h. diptera (two winged)
   i. hymen (membrane)
   j. hymenoptera (membraned wing)
   k. lepid (scale)
   l. lepidoptera (scaled wing)
   m. koleos (sheath)
   n. coleoptera (sheathed wing)
   o. thysanos (bristle)
   p. oura (tail)
   q. thysanura (bristle tail)

3. Special features of each of six orders. Identify:

   a. Thysanura (no wings, bristle tail)
   b. Orthoptera (straight winged)
   c. Diptera (two winged, spread disease)
   d. Lepidoptera (scale winged, two sets of wing pairs)
   e. Hymenoptera (membraned winged—except for ant with none, social insects)
   f. Coleoptera (two wing pairs, outer wings hard and sheath-like, order with largest numbers in variety)

4. Association of specific insects with order name. Identify member or members of each of the following six orders (or conversely, identify order name to which specific insect belongs):

   a. Thysanura (silverfish)
   b. Orthoptera (grasshopper, cricket, mantid, cockroach)
   c. Diptera (fly, mosquito)
   d. Lepidoptera (butterfly, moth)
   e. Hymenoptera (ant, bee, wasp)
   f. Coleoptera (beetle)

5. Life cycles. Describe each of three types of life cycles:

   a. No metamorphosis (no change in body appearance, except growth, from emerging from egg to adult)
   b. Gradual metamorphosis (nymph emerging from egg resembles adult except in size and absence of wings)
c. Complete metamorphosis (four distinct stages: egg; larval—wormlike, much eating and growth; pupal—quiescent, body changes occur in formation of adult structures; adult—full mobility, mating and reproduction)

6. Association of given insect order with life cycle type. Identify life cycle type for each of the six orders studied:
   a. Thysanura (no metamorphosis)
   b. Orthoptera (gradual metamorphosis)
   c. All other four orders (complete metamorphosis)

7. Names of life cycles for specific insect forms. Identify life cycle state represented by:
   a. fly maggot (larval)
   b. butterfly or moth caterpillar (larval)
   c. butterfly chrysalis or moth cocoon (pupal)
   d. grasshopper or other orthopteran between egg stage and adult (nymph)

8. Main body parts. Identify name of main body part associated with following features:
   a. middle, wings and legs attached (Thorax)
   b. anterior, antenna and mouth parts attached (Head)
   c. posterior end (abdomen)

9. Insect body processes and specific organs. Identify and/or describe insect body processes and, where applicable, specific organs involved in the process:
   a. metamorphosis (process of body changes in life cycle)
   b. molting (process of shedding exoskeleton to accommodate growth)
   c. breathing (tracheae, spiricals, expansion and contraction of abdomen required)
   d. circulation (heart, aorta, hemocoel—in which blood surrounds organs)
   e. smell (located on antenna, also touch is located on antenna)
   f. taste (feet, mouth parts)
   g. hearing (located in grasshopper just behind hind legs on abdomen)
In preparing the lesson, heavy reliance was placed on a text reference (Hegner and Stiles, 1951) and a biologist whose specialty is entomology and who reviewed the material prior to its use.

The following is an excerpt from the Insect lesson script.

On the right hand side of the page is a description of the visual cues, mounted on 11-inch x 14-inch panels, which appear on the screen at the time that the sound narrative, shown on the left, is heard. Quote marks ("...") indicate the showing of actual words. Words or a figure on a given panel may be momentarily obscured and hence masked; the same word or figure when exposed then becomes unmasked. The abbreviation, n.p., indicates a new panel placed on the screen. In the sound narrative, each question is followed by a pause interval with length indicated in the parentheses.

Excerpt from Lesson Script on Insects

Sound Narrative

One of the most primitive orders is Thysanura, meaning tasseltail in Greek. The name is suggestive of the bristletail found on members of this order. Pictured here is the silverfish which is a member of this order.

Question 11. The silverfish with its tassel-like bristletail is a member of what order? (6 seconds)

The answer is Thysanura.

Question 12. The word Thysanura is derived from Greek where it means what? (5 seconds)

Visuals


Mask "Thysanura—Tasseltail."

Unmask "Thysanura."

27John Heading, Department of Biology, Madison College.
The answer is tasseltail.

The order Orthoptera, includes cockroaches, mantids, crickets as well as the one pictured here.

Question 13. What name would you give the one you see on the screen? (6 seconds)

You see a grasshopper.

The name of the order Orthoptera, broken down into two parts, Ortho and Ptera, suggests a certain type of wing structure. The names of insect orders are often, but not always, suggestive of the type of wings that its adult members might have. The suffix, ptera, in Greek means wing. The prefix, ortho, in Greek means straight.

Question 14. The word Orthoptera, suggests what two word phrase describing a structure of this particular order? (7 seconds)

The answer is straight wing.

Note: The complete script appears in Appendix A.

Lesson Content Mathematical: Machines.--The content here requires a modicum of verbal skill of the learner but as important or more so is the ability to comprehend and use mathematical relations. This particular lesson will be identified as a mathematical content type. Successful mastery of the criterion items pertaining to the topic areas above implies that not only will the learner have the basic mathematical idea in mind, but will also be able to perform the needed arithmetic operation. The lesson deals with two simple machines, the lever and inclined plane, with much greater emphasis on the latter.
The simple machine in this context is regarded as a device into which some agent does work by applying a force over a given distance to lift an object a given height resulting in a portion of the original work done being dissipated. The topic outline areas which served as a basis for the lesson are shown here:

1. Computation of actual mechanical advantage (AMA), ideal mechanical advantage (IMA) and efficiency (Eff) for an inclined plane or simple lever, given the pertinent force, distance or energy quantities.
   a. \( \text{AMA} = \frac{\text{Object Weight}}{\text{Force Applied}} \)
   b. \( \text{IMA} = \frac{\text{Distance Force Applied}}{\text{Distance Object Lifted}} \)
   c. \( \text{Eff} = \frac{\text{Potential Energy Gain}}{\text{Work Done}} \)

2. Computation of energy dissipated or potential energy gained, given efficiency and work done.
   a. \( \text{Energy Dissipated} = \text{Work Done} \times (1 - \text{Eff}) \)
   b. \( \text{Potential Energy Gained} = \text{Work Done} \times \text{Eff} \)

3. Computation of one of three energy quantities, (1) Work Done, (2) Potential Energy Gained, (3) Energy Dissipated, when an object is pulled up an inclined plane, given the other two. In all such processes it will be assumed that the object has no net gain in kinetic energy at the end of the process.
   a. \( \text{Work Done} = \text{Potential Energy} + \text{Energy Dissipated} \)
   b. \( \text{Potential Energy} = \text{Work Done} - \text{Energy Dissipated} \)
   c. \( \text{Energy Dissipated} = \text{Work Done} - \text{Potential Energy} \)

4. Computation of each of the three pertinent energy quantities in the inclined plane process as a product of pertinent force (or weight) and plane dimension.
   a. \( \text{Work Done} = \text{Force Applied} \times \text{Plane Length} \)
   b. \( \text{Potential Energy} = \text{Object Weight} \times \text{Plane Height} \)
   c. \( \text{Energy Dissipated} = \text{Force Friction} \times \text{Plane Length} \)

5. Compute force (or weight) in inclined plane process as quotient of pertinent energy value divided by plane dimension.
   a. \( \text{Force Applied} = \frac{\text{Work Done}}{\text{Plane Length}} \)
   b. \( \text{Object Weight} = \frac{\text{Potential Energy}}{\text{Plane Height}} \)
   c. \( \text{Force Friction} = \frac{\text{Energy Dissipated}}{\text{Plane Length}} \)
6. Computation of energy value as the sum or difference of products of pertinent force (or weight) and plane dimensions. This incorporates steps 3 and 4 above.

   a. Work Done = 
      \[(\text{Object Weight} \times \text{Plane Height}) + (\text{Force Friction} \times \text{Plane Length})\]

   b. Potential Energy = 
      \[(\text{Force Applied} \times \text{Plane Length}) - (\text{Force Friction} \times \text{Plane Length})\]

   c. Energy Dissipated = 
      \[(\text{Force Applied} \times \text{Plane Length}) - (\text{Object Weight} \times \text{Plane Height})\]

7. Computation of force (or weight) as the quotient of sum or difference of products of pertinent forces (or weight) and plane dimensions divided by pertinent plane dimension. This incorporates steps 5 and 6 above.

   a. Force Applied = 
      \[
      \frac{(\text{Object Weight} \times \text{Plane Height}) + (\text{Force Friction} \times \text{Plane Length})}{\text{Plane Length}}
      \]

   b. Object Weight = 
      \[
      \frac{(\text{Force Applied} \times \text{Plane Length}) - (\text{Force Friction} \times \text{Plane Length})}{\text{Plane Height}}
      \]

   c. Force Friction = 
      \[
      \frac{(\text{Force Applied} \times \text{Plane Length}) - (\text{Object Weight} \times \text{Plane Height})}{\text{Plane Length}}
      \]

The programmed lesson script followed a rule-eg format where ideas and formulas are first defined, then followed by an example. An excerpt from the script below illustrates its form:

Excerpt from Lesson Script on Simple Machines

Sound Narrative
If you know the machine efficiency and work done, it is possible to find the potential energy gained.

Visuals
n.p. Show "P.E., EFF., W.D."

Question 12. Write a formula expressing PE in terms of EFF and WD (10 seconds)
Since \( \text{EFF} \) equals \( \text{PE} \) divided by \( \text{WD} \), then it follows that \( \text{PE} \) equals \( \text{EFF} \) times \( \text{WD} \).

Let's take a numerical example.

**Question 13.** If work done in lifting a simple machine is 200 foot-pounds, and efficiency is eight-tenths, then what is the potential energy gained? (8 seconds)

\( \text{P.E.} = \text{EFF. \times W.D.} \)

Unmask "\( \text{P.E.} = \text{EFF. \times W.D.} \)"

We have emphasized that with the simple lifting machine, the potential energy gained cannot exceed work done.

Also when frictional forces are present as they inevitably must be in a real process, at least some of that work done is dissipated as heat.

We'll adopt another symbol, \( \text{ED} \) to represent this energy dissipated.

Remember, the difference between the work done, and useful energy out, is the energy dissipated.

Note: The complete script appears in Appendix A.

**Revision of Pilot Lessons.** A critical decision was taken prior to the writing of the final lesson versions, namely to expand the content over that used in the pilot lessons and to subdivide each into two parts, each to be presented at a different class meeting.

This step was prompted by two reasons: (1) With a larger body of content covered over a longer time period, it was believed that any real treatment effect would more likely be apparent.  

(2) It was

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28Suggested by John Stock, psychologist, Battelle Institute.
suggested by students taking the pilot lessons on Simple Machines that more examples be given during the lesson; this provision was added to the final version and meant more total lesson time was needed. Topic area 9 from Insects and areas 1 and 2 from Simple Machines constitute the content that was added.

Production of Visuals and Sound Narrative.—Visuals for the final lesson versions were mounted on grey 11-inch x 14-inch poster board panels. Services and materials for this work were provided by the Instructional Media Center at Madison College. Partial sections of a given panel could be covered by using a masking sheet that could be swung across the panel or back. A total of fifty-one panels were used with the Insect lesson and eighty-eight with Simple Machines.

The sound narrative was recorded on audio tape by a male senior speech major at Madison College. He was instructed to read directly from the lesson script at his normal speaking rate, being sure however to allow for the prescribed pause time after each question. Also, a very slight pause was inserted where a comma or period appeared in the expository passages, primarily to facilitate future pause editing.

Production of Video-Tape Lessons.—The lessons were recorded using a one-inch Ampex Video Tape Recorder in the closed circuit television studio at Madison College.

The previously taped sound narrative was fed from the audio playback directly into the video recorder sound system. Pause intervals were regulated by a member of the studio crew who operated the
Instant stop-start switch on the audio tape recorder. This arrangement for inserting these intervals was not as precise as might have been desired. An electric clock with sweep hand was used to guide the start-stop switch operator; this involved a dependence on the eye-hand coordination by that individual. Under such arrangement, it would be reasonable to expect a plus-or-minus one second deviation in the actual pause period from that prescribed in the script.

The Programmed Lesson and Pace Rate Control.—The mechanics of systematically controlling the pace rate became a critical step in developing the four lesson versions. First, it was important to define the important elements in a given frame. Visual elements consist of (1) written key words, (2) written formulas, (3) sketches or pictures, (4) objects and (5) persons. Aural elements consist of (1) expository sentences followed in each case by (2) the appropriate frame question and then (3) the feedback answer to the preceding frame question.

Most significantly, the aural elements are interspersed with pauses. It was presumed that the most critical aural pause periods in the program are those that occur either (1) in conjunction with a given key visual or aural element within the expository passages or (2) at the time that an active response is desired from the student. Variations in program pace were thus manipulated by adjusting the time allowed in the pause interval at either or both of these two points in the program.

The minimum pause time at a response point is that interval in which the learner may reasonably be expected to actively respond to the question or task posed. For example, approximately five seconds were
found needed to write the word "metamorphosis" on a response sheet and approximately ten seconds to perform a simple numerical calculation on paper such as "30 x 5 - 10 x 2" and write the final result as "130."

The minimum pause time allowance at a key expository point is that which the speaker would normally supply at the end of a phrase or sentence, that generally needed to catch the breath before continuing on—at most, a second of time.

The fastest pace version that may be reasonably allowed is that which includes only the minimum pause time intervals. All those at a slower pace will have the additional time added at either the key expository points, response points or both.

At the outset of the study, the decision was made to develop the four lesson versions so that the times allowed for the extreme pace versions (slowest and fastest) would be in an approximate 2:1 ratio. The fastest version corresponded to the pace set on the original audio tape sound narrative. Only the minimum pause intervals were used and included at the time of the script reading. The following set of guidelines were established which were used systematically to prescribe additional pause time allowances:

1. At response points, double the minimum pause time. If five seconds represent the minimum time to respond with the written word "metamorphosis," then ten seconds were used in the extended version.

2. At key expository points, add from 3 to 10 seconds, this interval to depend upon the nature of the cue at that point.
The various types of such cues are categorized here showing the pause time prescribed for each:

a. Familiar word or symbol: add 3 seconds.

b. Word or symbol not generally familiar and introduced for first time into the lesson: add 6 seconds.

c. At the end of any sentence or key phrase: add 6 seconds.

d. Extended formula, definition or key phrase: add 10 seconds.

Also, in the Full Pause version (where pauses were added at both response points and expository points) the pause periods prescribed at points b and c above, as well as at the response points were augmented further by two seconds. This was a last-minute insertion made to bring the time allowance ratio between the extremes in slow and fast paces closer to 2:1.

The following is a typical passage from the Insect lesson. The number in parentheses represents the number of seconds pause time at key points; the first of the pair is the minimum time allowed.

Insects in the order Orthoptera emerge from the egg with a similar but not identical appearance to the adult. The young grasshopper is called a nymph, (0,6) has no wings, (0,6) and has a proportionately larger head compared to the rest of its body, (0,10) Orthopterans are said to undergo gradual metamorphosis. (0,6)

Question 21. What is the name of the grasshopper stage after it emerges from the egg? (4,8)

The very young grasshopper emerging from the egg is called the nymph. (0,6)

The exoskeleton on an insect does not grow with the rest of the body. To accommodate the increasing size as the insect matures, it must shed the exoskeleton in a process called molting. (0,6)
Question 22. Molting is the process that accompanies the insect's changing in what characteristic? (4,8)

Size changes, necessitate molting. (0,6)

The above passage with just the minimum pauses included requires about sixty seconds. Pauses added after responses alone over the minimum prescribed would account for 8 seconds more or a total now of 68 seconds. Pauses added after key expository points over the minimum prescribed would combine 46 seconds more to give a full pause total of 114 seconds.

Study Pace Versions.—Four pace versions were produced on video-tape for each lesson, each identified according to the form of pause time allowance:

Full Pause Version—Pauses added at both key expository points and at response points.

No Pause Version—Minimum pause time at both key expository points and response points.

Question Pause Version—Minimum pause time at key expository points and pauses added at response points.

Expository Pause Version—Pauses added at key expository points and minimum pause time at response points.

The table below shows the total time and time per frame for each version of the two lessons. It will be noted that the Insect content times-per-frame range from .42 to .80 minutes for a ratio of 1.91, while the Simple Machines content varies from .97 to 1.79 minutes, a ratio of 1.85. These values are roughly within the ranges suggested by the external pacing studies of Janin29, Gallegos30 and Eckhardt.31

29Janin, op. cit.
30Gallegos, op. cit.
31Eckhardt, op. cit.
TABLE 1.—Time allowance, total and per frame, four versions of video-taped Insects lesson

<table>
<thead>
<tr>
<th>Version</th>
<th>Total Time (min.)</th>
<th>Number of Frames</th>
<th>Time Per Frame (min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Pause¹</td>
<td>37.5</td>
<td>89</td>
<td>.42</td>
</tr>
<tr>
<td>Question Pause</td>
<td>45.0</td>
<td>89</td>
<td>.51</td>
</tr>
<tr>
<td>Expository Pause</td>
<td>55.0</td>
<td>89</td>
<td>.62</td>
</tr>
<tr>
<td>Full Pause¹</td>
<td>71.5</td>
<td>89</td>
<td>.80</td>
</tr>
</tbody>
</table>

¹Ratio of slowest pace (Full Pause) to fastest (No Pause): 1.91
²Each question asked constitutes a single frame.

TABLE 2.—Time allowance, total and per frame, four versions of video-taped Simple Machines lesson

<table>
<thead>
<tr>
<th>Version</th>
<th>Total Time (min.)</th>
<th>Number of Frames</th>
<th>Time Per Frame (min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Pause¹</td>
<td>50.5</td>
<td>52</td>
<td>.97</td>
</tr>
<tr>
<td>Question Pause</td>
<td>57.5</td>
<td>52</td>
<td>1.11</td>
</tr>
<tr>
<td>Expository Pause</td>
<td>82.0</td>
<td>52</td>
<td>1.58</td>
</tr>
<tr>
<td>Full Pause¹</td>
<td>93.0</td>
<td>52</td>
<td>1.79</td>
</tr>
</tbody>
</table>

¹Ratio of slowest pace (Full Pause) to fastest (No Pause): 1.84
²Each question asked constitutes a single frame.

Criterion Instruments

The criterion measures used for the study were: (1) a pretest over content in both lessons, administered at the first class meeting of the semesters; (2) program response performance, the number of correct responses made by learners while presented with the instruction; (3) immediate posttests, administered in all cases just after instruction
was completed within a given class session; (4) delayed posttests, given over the same material in the week following completion of instruction; and (5) Scholastic Aptitude Test scores, obtained from the Office of Student Services at Madison College.

All of the tests constructed specifically for the study made use of a short answer restricted response item. One additional condition was provided in the insect pretest where a list of possible answers preceded the items; prior experience in pilot testing indicated that without this prompting assistance, subjects who had not recently encountered the content would answer practically none correctly.

Certain compromises were made in determining the length of the pretests and delayed posttests. It was felt that if a too sizeable portion of course time was devoted strictly to testing over just that content pertaining to the study, a morale problem could arise. For this reason both pretests and delayed posttests were abridged versions of the immediate posttests. It was possible to get a measure of learning gain by comparing score percentages using only those same items that appear on both pretest and immediate posttests. Similarly, an estimate of forgetting was made by looking at the same items on both immediate and delayed posttests.

The Pretests.—The pretest items were incorporated into a larger test which covered general topic areas included in the entire course. In addition to pretest items over Insects and Simple Machines, another ten-item subtest was included over Math Skills needed specifically for solving the questions posed in the latter lesson. The entire
pretest consisted of 90 items, 43 on general material, 22 on insects, 15 on Simple Machines and 10 on Math Skills.

The lack of success on the 15-item Simple Machines pretest (average less than 1% correct) was such that no effort was made to use this instrument in any subsequent analysis. Appendix B shows those items on the Math Skills test and also indicates those from the Insect immediate posttest which also were used on the pretest.

Response Performance.--It is somewhat difficult to separate this particular measure from the programmed lesson itself since it is this source that prompts the learner responses. On the Insect lesson there were 89 possible response items, each corresponding to a lesson frame, 45 and 44 on parts I and II, respectively. Simple Machines totaled 52 Items, 26 on each part. Answers were written on sheets prepared with numbered blanks. A work-scratch space was provided on the answer sheet for which numerical calculations were necessary.

Immediate Posttests.--Immediate posttests for both lessons were constructed in two parts to conform to the lesson parts. Questions were prepared on mimeographed sheets on which students were asked not to write; answer sheets showing the appropriately numbered blanks were distributed separately. A blank section for scratch work calculation was provided on the Simple Machines answer sheet. An item analysis for this instrument is given in Appendix C.

Immediate Posttest: Insects.--This instrument consisted of 75 total items, 39 and 36 on parts I and II. Appendix C gives a breakdown of item-by-item coverage by lesson frames and also by topic areas. The
distribution of items by topic area was determined largely by having the posttest conform as much as possible to the lesson frame content. Items were reviewed by two individuals for content analysis.

Within the Insect lesson posttest two specific types of items were identified according to their similarity to response questions asked during the programmed lessons: (1) Direct items were those that are essentially identical to those posed during the lesson and (2) Indirect items, those which pertain to content in specific lesson frames but which were not posed specifically during the lesson for a student response. Of the 75 total, 48 items were direct for which the average difficulty was 16 per cent missed compared to the 24 per cent found for the remaining 27 items.

The test lengths for each part were designed to conform to the length of class periods of one hour and fifteen minutes to assure that the very slowest students in the full pause group (this lesson version consuming the most time) would have ample time to finish. With approximately 40 minutes being consumed by instruction for each lesson part, including preparations, then at least 35 minutes remained for the immediate posttest, a period that previous experience in the pilot study showed to be sufficient. This provision for adequate time was considered important in order to assure that subjects in all treatment groups were able to cover all items.

32 John Heading, Department of Biology, Madison College and Jerry O. Haynes, Department of Psychology, Madison College.
The Kuder-Richardson-20 formula based on the item analysis and standard deviation for the test gives a reliability of .88. Two examples, illustrative of the items used, are shown here:

1. What is the main body part to which the insect's wings are attached?

2. What name is given to the cockroach individual just after it emerges from the egg? (Appendix B gives the complete set of posttest items.)

Immediate Posttest: Simple Machines.—This instrument consisted of 39 items, 20 and 19 on parts I and II, respectively. Again the lengths of both parts were determined by consideration of time. Items were reviewed by three individuals\textsuperscript{33} for content analysis.

None of the Immediate posttest items were exact replicas of those that appeared as questions in the programmed lesson. However, the essential difference was in the numerical values placed in the problems.

All items on the Simple Machines posttest required a numerical answer. The numerical values in the context of each were specifically chosen so that the need to manipulate awkward fractions and decimals in arriving at an answer might be avoided. Two examples typical of the items used are shown:

1. If an object gains 500 foot-pounds of potential energy when lifted up an incline of length 20 feet and height 5 feet, then what is the object weight (in pounds)?

2. If a simple lifting machine has an efficiency of .4 and work done is 500 foot-pounds, then what is the energy dissipated?

\textsuperscript{33}Jon Staib, Robert Gordon, and John Wells, all of the Physics Department, Madison College.
The Kuder-Richardson-20 formula gives a reliability of .93 for this instrument. Appendix B gives the complete set of items and Appendix C gives an item analysis and coverage by lesson frames and by topic areas.

Delayed Posttests.—Both of these instruments were constructed of items taken from the immediate posttests, with the qualification that Simple Machine items had revised numerical values.

As indicated previously, the reduction in the number of items from those used in the immediate posttest was prompted by considerations of time budgeting, hence the use on only 50 items on the Insects delayed posttest and 25 on that for Simple Machines. Item selection for the Insects delayed posttest was by use of a random number determination from immediate posttest items. The Simple Machines selection was made tentatively on a random basis but was then modified to assure a more even distribution of topic areas.

An assumption was made that items drawn in this manner from a larger pool (the immediate posttests) to form the abbreviated version will test essentially the same content. This assumption was put to an empirical examination by comparing average results of the entire test to that subtest of items placed on the delayed posttest when both are administered in the immediate posttest condition. Two questions thus may be asked: (1) Will both show the same percentage difficulty with the same learners? and perhaps even more critical (2) Will both show the same treatment effect differences (if such exist)? The data reported in the chapter to follow gives the result of comparisons for both content tests.
The Kuder-Richardson-20 reliabilities for the Insects and Simple Machines delayed posttests are respectively .90 and .96. Appendix B shows which items were drawn from the immediate posttest for use in these instruments.

Scholastic Aptitude Tests: Verbal and Mathematical.—The Scholastic Aptitude Test (SAT) scores were provided by the Office of Student Services of Madison College for the subjects in the study. This criterion was the basis for the aptitude variable. Two scores are reported, verbal and mathematical.

The choice of this particular instrument was dictated by (1) the ready accessibility of these scores, (2) its seeming appropriateness to meeting the objectives of the study in providing an independent aptitude variable and (3) the general acknowledgment of its high reputation when evaluated along with other standardized instruments used in comparable contexts.

The following pertinent data is given in the Seventh Mental Measurements Yearbook in regard to the SAT.

Mean Score Standardized—500

Internal Reliabilities—Verbal: .91
Math: .90

Parallel Form Reliabilities—
Verbal: .89
Math: .88

Validity with College Records—
Verbal: .39
Math: .33

Instructional and Testing Procedures

This section will describe the setting of the course from which subjects for the study were derived along with the procedures and schedule of the instruction and testing.

Subjects. -- Subjects in the study were elementary or special education majors in the junior or senior year at Madison College and were enrolled in the spring semester, 1972, course titled Science For Elementary Teachers; all but one were female.

Course Description. -- Classes met on Tuesdays and Thursdays of each week, there being three separate sections with class periods of one hour and fifteen minutes. Students were also assigned to a weekly two-hour laboratory section. The chief objective of the Tuesday-Thursday class periods was instruction in science content material while the lab sessions were designed to acquaint students with science teaching methods in the elementary school. The course was shared by two instructors.35

A set of general course instructions was distributed to students at the beginning of the semester. These instructions concluded with the following passage, the object being to alert students to the prospect of their participation in the study.

In at least four class periods, the instruction will be conducted using video-taped programmed lessons. These lessons have been developed for use as a part of a research project and will be accompanied by a series of posttests that are designed to measure the learning effectiveness.

35John C. Wells and this writer, Physics Department, Madison College.
On the class meeting day just prior to the first video-taped instruction, the following memo was distributed to all sections:

One of the activities of this course is a research project in learning to use programmed lessons prepared and presented on video tape.

Different versions of the same lesson content will be presented to two groups at one time in separate viewing rooms. Once the lessons are completed, a follow-up test will be given immediately to all students to measure the learning outcomes. The object of the study is to determine if one lesson version is superior to another.

A lesson will consist of two segments, each to be presented on a different class day. A delayed follow-up test will be given one week after the completion of the second segment.

Details as to how these versions differ from each other and the final results of the learning outcome comparisons will be discussed with the class once all the lessons and follow-up tests have been completed.

The content of these lessons will be covered on the regular course tests. Test scores will be adjusted upward for students who appear to have been penalized by having received instruction from a less effective lesson version. Also, just prior to the scheduled course test, a review session will be set up for those who, after receiving the video-tape lessons and taking the follow-up tests, still desire additional instruction over the content.

You are asked to cooperate by doing the following. Please:

1. Make every effort to be present on all the lesson presentation and test days. The comparative results will have validity only if there is nearly 100% participation by the class.

2. Do not study out of class the particular content from these video-taped lessons until after having taken the delayed follow-up test. This rather unusual instruction stems from the need to strictly compare the effectiveness of the videotaped lessons versions. Ample opportunity will be given to study out of class after the delayed test.

Your participation in this endeavor will be appreciated. Thank you.
Under the then existing college rules a student's grade was not to be determined by his or her attendance record. Consequently, for some there is little motivation to be present if it is known that a given day's class activity has nothing to do with what may later appear on an exam. The intent of the above memo was to provide incentive for attendance and yet dispel student fears that they would not have equal opportunity on course exams by virtue of being placed in one treatment group or another.

The above effort to assure good attendance for the instructional and posttest sessions was not entirely successful. Of the total course enrollment of 105, only 78 were present for both sessions of the Insects lesson and 83 for both Simple Machines sessions. A college choir trip was partially responsible for the attrition in the first instance.

One circumstance of the decision to give both lessons and immediate posttests in two parts and in two successive class periods was that the original groups chosen by random number on the first day of the lesson sessions were not entirely intact for both sessions. Some students did not attend class for that second session. A tentative assumption is made that the dropout loss incurred between the two sessions represents a random subsample from the initial group; this assumption is tested by comparing full group means of immediate posttest scores on part I to the final group (full sample minus dropouts) immediate posttest results on the total of both parts. This is reported in Tables 15 and 31 of Chapter V.
Complete use of all subjects in the original groups chosen for total analysis of data was also ruled out by the fact that no Scholastic Aptitude Test scores were available for a certain proportion of individuals.

Calendar Schedule.--The following schedule of instruction and testing was used:

February 3--Pretest
March 9----Insects-Part I, Instruction and Immediate Posttest
March 14----Insects-Part II, Instruction and Immediate Posttest
March 21----Insects, Delayed Posttest
April 25----Simple Machines-Part I, Instruction and Immediate Posttest
April 27----Simple Machines-Part II, Instruction and Immediate Posttest
May 2----Simple Machines, Delayed Posttest

Pretest.--As was discussed in the preceding section, a pretest covering material on Insects, Simple Machines and Math Skills along with other areas of the course was administered in the first class meeting period of the semester.

Treatment Group Selection.--Subjects attending the third and eighth period classes were separated into two groups, each to receive either the Full Pause Version or the No Pause Version lessons. Subjects attending the fourth period class were separated into the two groups receiving either the Expository Pause Version or the Question Pause Version.

Group assignments were made by placing a code symbol, either "I" or "II", according to random number designation on the response sheets distributed prior to the first instructional session of each
lesson. Those receiving a response sheet coded "I" were in the Full Pause Group if in periods 3 or 8 and in the Expository Pause Group if in period 4. Accordingly, "II" subjects were either in the No Pause Group (if periods 3 or 8) or the Question Pause Group (if period 4).

Special Conditions.—Two viewing rooms were available for a given class period, one being the regular classroom with three 24-inch monitors, and another room on the same hall equipped with two 24-inch monitors. Seating was such that no student needed to be more than twelve feet from a monitor.

Since the lessons for group "I" consumed more time in all periods, these subjects were assigned to remain in the regular classroom, while the "II" groups went to the second viewing rooms. This measure was taken in order to conserve class time for the groups having the longer lessons.

Students were requested to answer questions posed by the taped lesson on the blanks provided on the response sheets. If an answer was found to be incorrect, the student was permitted to write in the correct answer after hearing it given, but was asked to so indicate with a check mark.

No close supervision was made of subjects during the instruction although the instructor was present in one or the other of the two viewing rooms, primarily to assure that the picture and sound functioned satisfactorily.
Upon completion of the lesson, response sheets were turned in and immediate posttest question and answer sheets were distributed. Subjects were excused for the class period after completing the test.

Delayed Posttests.—The last 35 minutes of the class period of the Tuesday following the instruction session were reserved for the delayed posttests; this constituted a span of seven days for the Insects and five days for Simple Machines between instruction and delayed posttest. In both instances intervening instruction given to the classes was on material unrelated to the study content.

Analysis of the Data

This section will describe the method and rationale of the data analysis used for testing the four null hypotheses of the study. For convenience, the hypotheses are stated here again:

1. An increase in learning time will not significantly result in an increase of either of the dependent variables, learning performance and effectiveness.

2. Learner aptitude will have no significant effect on either of the dependent variables, learning performance and effectiveness.

3. There will be no significant interaction between learning time and learner aptitude as they effect either of the dependent variables, learning performance and effectiveness.

4. A variation in the placement of pause intervals within the programmed lesson will not significantly effect either of the dependent variables, learning performance and effectiveness.
For convenience again, the dependent and independent variables of the study are restated, the first three serving as dependent:

1. Learning performance, measured by score on responses made by the learner during program instruction.

2. Learning effectiveness immediate, measured by score on posttests taken immediately after instruction.

3. Learning effectiveness delayed, measured by score on post-test taken five to seven days after completion of instruction.

4. Aptitude variables, which consist of the Scholastic Aptitude Test scores, Verbal and Mathematical, each being used in the analysis for that portion of the study to which it is applicable to the particular content.

5. Treatment variables which are manipulatable according to either a) the total amount of time made available to the learner or b) the pattern by which pause intervals are introduced into the lesson.

6. Pretest scores on Insects and Math Skills will serve as covariates in a portion of the analysis.

Conditions of the Study.—Certain practical and theoretical conditions of the study, pertinent to the method of data analysis, are detailed here:

1. Subjects who were assigned to the No Pause and Full Pause treatments, representing the extremes in total learning time available, were chosen from the same population (the 3rd and 8th class periods), while those in the Expository Pause and Question groups came from another subject pool (4th period). Due to the fact that subjects in the latter treatment groups came from only one class period, the N-size in these two were somewhat limited.

2. For a certain proportion of subjects who were assigned originally to the treatment groups, aptitude scores were missing. This
obviously necessitates using a smaller number of cases for those analyses involving this particular variable. This fact, combined with the condition 1 above and also the attrition of subjects between the first and second sessions for each lesson, means that the assumption of randomized sampling cannot be altogether maintained.

3. The total time available may best be handled as an ordinal variable when comparing just the Full Pause and No Pause groups. It is a reasonable a priori assertion that the latter group had available less time. When all four treatments are involved, however, it is more difficult to legitimately treat gross time available as an ordinal quantity, even though certainly the running clock time is measurable. This stems from lack of information about the relative importance of pauses placed either at the expository portions of the lesson or at the response points. For this reason a nominal scale seems more appropriate when analyzing all four groups at one time.

4. The discussion in Chapter III suggests that (within limits) when more learning time is available, the mean learning criterion scores will be greater. A test of this proposition would thus involve comparison of two treatment groups for which gross learning time can unequivocally be said to be different; furthermore, a directional, or one-tailed, significance test would seem indicated here.

Test of the Hypotheses.—In the discussion that follows, each of the individual hypotheses and the specific method for testing will be examined.
Hypothesis One: A one-tailed t-test of significance was applied in comparing means of the Full Pause and No Pause groups on all criterion scores. The rationale for the one-tailed decision is set forth in point 4 above. Only these two groups were involved here because of the conditions set forth in 3 above.

Hypotheses Two and Three: A 3 x 2 aptitude by treatment factorial design was applied to test the second and third hypotheses again using only the Full Pause and No Pause groups, but without those cases for whom Scholastic Aptitude Test scores were unavailable. The smaller number of cases in the other two treatments and the positively skewed distribution of aptitude scores in these two groups made unfeasible a four treatment analysis in this case. The result of attempting this would be to have had some cells with only one or even no cases present. Subjects were assigned to the aptitude cells identified as high, medium or low. The criteria for determining number of cells for this factor and the range within a given cell was based on the effort to maintain as nearly as possible equal numbers of cases among cells. The aptitude score range per cell is reported with the data in the next chapter. The second and third hypotheses rested on the F-test for the ratios associated with the aptitude levels and the aptitude by treatments interaction respectively.

Hypothesis Four: In making a simultaneous comparison of all four pace treatments, a one-way analysis of variance was used, with the F-test serving as the criterion. Because two of the treatment groups came from a different subject pool than the other two, the Independent
variables, aptitude and pretest scores, were introduced as covariates as a means of providing a more equitable comparison.

Significance Level.—The .05 level was adopted as the rejection point for the null hypotheses. The t or F ratios along with the p value, indicating the level of significance, were reported.

Comparison of Groups by Aptitude and Pretest Scores.—An examination of the homogeneity of the treatment groups was done by a one-way analysis of variance using the aptitude and pretest scores as criteria. The Math Skills pretest was used in this context, as well as in the covariate analysis, instead of the Simple Machines pretest which was abandoned for this purpose due to the very little success that learners had with it in the pretest setting.

Strength of Association.—A criterion less commonly employed was also applied in the interpretation of the data. This is the strength of association index, symbolized by $\omega^2$ (Greek omega squared), sometimes defined as the proportion of variance in the dependent variable accounted for by the independent variable(s).36 The particular formulas used for estimating the $\omega^2$ values in those analyses showing significance are given in Appendix D.

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CHAPTER V

PRESENTATION OF DATA AND DATA ANALYSIS

Introduction

The analysis of the data taken from the study is detailed in this present chapter. It is organized into two main sections, the first to deal with data pertaining to the verbal content lessons (Insects) and the second, with the lessons in mathematical content (Simple Machines).

Within each section the four study hypotheses will be the specific target of analyses in the first nine tables. Seven additional tables in the first section and six in the second are also included to provide supplementary data. Hence, the basic chapter outline becomes:

1. Data analysis applied to the four study hypotheses, verbal content lessons. Tables 3-11.


3. Data analysis applied to the four study hypotheses, mathematical content lessons. Tables 19-27.

4. Supplementary data, mathematical content lessons, Tables 28-33.

5. Overall summary.
Insect Lesson Data

Tables 3, 4 and 5: Test of Hypothesis One. The hypothesis reads:

1. An increase in learning time will not significantly result in an increase of either of the dependent variables, learning performance and effectiveness.

The one-tailed t-test was applied in each of these three analyses which compared the Full Pause and No Pause groups.

**TABLE 3.** t-test comparison of Full Pause and No Pause groups on Insect lesson program learning performance (response scores)

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of Cases</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Pause</td>
<td>27</td>
<td>82.96</td>
<td>4.28</td>
</tr>
<tr>
<td>No Pause</td>
<td>24</td>
<td>77.25</td>
<td>6.55</td>
</tr>
</tbody>
</table>

Note: Difference in means = 5.71, \( t = 3.66, p < .001 \) (one tail), estimated \( \omega^2 = .20 \).

**TABLE 4.** t-test comparison of Full Pause and No Pause groups on Insect lesson program learning effectiveness in immediate posttest

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of Cases</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Pause</td>
<td>27</td>
<td>64.26</td>
<td>8.35</td>
</tr>
<tr>
<td>No Pause</td>
<td>24</td>
<td>59.04</td>
<td>9.67</td>
</tr>
</tbody>
</table>

Note: Difference in means = 5.22, \( t = 2.02, p < .025 \) (one tail), estimated \( \omega^2 = .06 \).
TABLE 5. — \( t \)-test comparison of Full Pause and No Pause groups on Insect lesson program learning effectiveness in delayed posttest

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of Cases</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Pause</td>
<td>26</td>
<td>32.65</td>
<td>10.18</td>
</tr>
<tr>
<td>No Pause</td>
<td>22</td>
<td>33.00</td>
<td>8.74</td>
</tr>
</tbody>
</table>

Note: Difference in means = -0.35, \( t \) not applicable in one tail test when difference in means is negative.

The most decided treatment effect occurs in the program performance (or response score) criterion where the Full Pause group is favored at the \( p < .001 \) level and the estimated strength of association is .20 (or 20%).

A difference at the \( p < .025 \) level favoring the Full Pause group is observed in the immediate posttest means and here the estimated strength of association is .06.

The delayed posttest results show no significant difference between the two treatments.

Tables 6, 7 and 8: Test of Hypotheses Two and Three.—The hypotheses read:

2. Learner aptitude will have no significant effect on either of the dependent variables, learning performance and effectiveness.

3. There will be no significant interaction between learning time and learner aptitude as they affect either of the dependent variables, learning performance and effectiveness.

Learner Scholastic Aptitude Test-Verbal (SAT-V) scores were the basis for aptitude level assignments. The placement within aptitude levels was determined by the following scale:
High level——SAT-V score above 498
Middle level——SAT-V score included in 433-498 range
Low level——SAT-V score below 433

A two-way, 3 x 2 analysis of variance was applied in this instance which gave a reading on both hypotheses in question.

TABLE 6.--3 x 2, Scholastic Aptitude Test-Verbal levels by treatments
analysis of variance of Insect lesson program learning
performance (response scores)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Level</th>
<th>Population</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Pause</td>
<td>High</td>
<td>7</td>
<td>84.29</td>
<td>4.27</td>
</tr>
<tr>
<td>Full Pause</td>
<td>Middle</td>
<td>8</td>
<td>82.38</td>
<td>5.26</td>
</tr>
<tr>
<td>Full Pause</td>
<td>Low</td>
<td>7</td>
<td>81.43</td>
<td>4.35</td>
</tr>
<tr>
<td>No Pause</td>
<td>High</td>
<td>4</td>
<td>78.50</td>
<td>7.94</td>
</tr>
<tr>
<td>No Pause</td>
<td>Middle</td>
<td>9</td>
<td>76.11</td>
<td>7.46</td>
</tr>
<tr>
<td>No Pause</td>
<td>Low</td>
<td>9</td>
<td>79.11</td>
<td>3.95</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>Degrees Freedom</th>
<th>Mean Sum Squares</th>
<th>F</th>
<th>p &lt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within Cells</td>
<td>1175.79</td>
<td>38</td>
<td>30.94</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatments (T)</td>
<td>265.09</td>
<td>1</td>
<td>265.09</td>
<td>8.57</td>
<td>.006</td>
</tr>
<tr>
<td>Aptitude (A)</td>
<td>37.13</td>
<td>2</td>
<td>18.56</td>
<td>.60</td>
<td>--</td>
</tr>
<tr>
<td>T x A</td>
<td>35.71</td>
<td>2</td>
<td>17.86</td>
<td>.58</td>
<td>--</td>
</tr>
</tbody>
</table>

The treatment effect, though obviously important in the above result, will not be examined further here since this was the chief object of concern in Table 3.

In the immediate posttest (Table 7) the aptitude level is shown significant at the $p < .05$ level. That the treatments effect is shown to be somewhat less important here than in the $t$-test of Table 4 may be accounted for by considering that the latter was based on a slightly larger and hence different $N$ group.
TABLE 7.—3 x 2, Scholastic Aptitude Test-Verbal levels by treatments, analysis of variance of Insect lesson program learning effectiveness in immediate posttest

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Level</th>
<th>Population</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Pause</td>
<td>High</td>
<td>7</td>
<td>66.57</td>
<td>6.45</td>
</tr>
<tr>
<td>Full Pause</td>
<td>Middle</td>
<td>8</td>
<td>65.38</td>
<td>6.16</td>
</tr>
<tr>
<td>Full Pause</td>
<td>Low</td>
<td>7</td>
<td>56.43</td>
<td>9.48</td>
</tr>
<tr>
<td>No Pause</td>
<td>High</td>
<td>4</td>
<td>67.25</td>
<td>9.32</td>
</tr>
<tr>
<td>No Pause</td>
<td>Middle</td>
<td>9</td>
<td>57.56</td>
<td>11.57</td>
</tr>
<tr>
<td>No Pause</td>
<td>Low</td>
<td>9</td>
<td>58.78</td>
<td>6.10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>Degrees of Freedom</th>
<th>Mean Sum of Squares</th>
<th>F</th>
<th>p &lt; 0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within Cells</td>
<td>2683.83</td>
<td>38</td>
<td>70.63</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatments (T)</td>
<td>105.09</td>
<td>1</td>
<td>105.09</td>
<td>1.49</td>
<td>.23</td>
</tr>
<tr>
<td>Aptitude (A)</td>
<td>477.13</td>
<td>2</td>
<td>238.57</td>
<td>3.38</td>
<td>.05</td>
</tr>
<tr>
<td>T x A</td>
<td>236.13</td>
<td>2</td>
<td>118.06</td>
<td>1.67</td>
<td>.20</td>
</tr>
</tbody>
</table>

Total: 3502.18

*Estimated $\omega^2$ (criterion with aptitude) = .09.

The interaction effect is not sufficiently strong to warrant rejection of null hypothesis three on this criterion although the trend of the data is suggestive, as Figure 4 serves to illustrate.

![Immediate posttest score mean plotted against aptitude level for each treatment, Full Pause and No Pause, Insect lesson.](image-url)
Table 8 indicates that none of the effects examined are important in regard to the delayed posttest.

TABLE 8.—3 x 2, Scholastic Aptitude Test-Verbal levels by treatments, analysis of variance of insect lesson program learning effectiveness in delayed posttest

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Level</th>
<th>Cell Population</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Pause</td>
<td>High</td>
<td>7</td>
<td>34.00</td>
<td>7.14</td>
</tr>
<tr>
<td>Full Pause</td>
<td>Middle</td>
<td>7</td>
<td>30.57</td>
<td>9.85</td>
</tr>
<tr>
<td>Full Pause</td>
<td>Low</td>
<td>7</td>
<td>28.29</td>
<td>13.72</td>
</tr>
<tr>
<td>No Pause</td>
<td>High</td>
<td>4</td>
<td>34.00</td>
<td>11.02</td>
</tr>
<tr>
<td>No Pause</td>
<td>Middle</td>
<td>8</td>
<td>33.25</td>
<td>11.07</td>
</tr>
<tr>
<td>No Pause</td>
<td>Low</td>
<td>8</td>
<td>32.25</td>
<td>7.28</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>Degrees Freedom</th>
<th>Mean Sum Squares</th>
<th>F</th>
<th>p&lt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within Cells</td>
<td>3610.14</td>
<td>35</td>
<td>103.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatments (T)</td>
<td>42.95</td>
<td>1</td>
<td>42.95</td>
<td>.42</td>
<td>--</td>
</tr>
<tr>
<td>Aptitude (A)</td>
<td>100.78</td>
<td>2</td>
<td>50.39</td>
<td>.49</td>
<td>--</td>
</tr>
<tr>
<td>T x A</td>
<td>24.03</td>
<td>2</td>
<td>12.01</td>
<td>.12</td>
<td>--</td>
</tr>
<tr>
<td>Total</td>
<td>3777.90</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Tables 9, 10 and 11: Test of Hypothesis Four.—The hypothesis reads:

4. A variation in the placement of pause intervals within the programmed lesson will not significantly affect either of the dependent variables, learning performance and effectiveness.

In this case an analysis of variance between levels is used with the Scholastic Aptitude Test-Verbal and Insects pretest introduced as covariates.
TABLE 9.---One-way analysis of variance with four treatments on insect lesson performance (response score)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of Cases</th>
<th>Response Scores</th>
<th>SAT-V^a</th>
<th>Insect Pretest^a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Pause</td>
<td>22</td>
<td>82.68</td>
<td>464.77</td>
<td>4.82</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.61</td>
<td>73.59</td>
<td>3.42</td>
</tr>
<tr>
<td>No Pause^c</td>
<td>22</td>
<td>77.77</td>
<td>469.50</td>
<td>5.14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.18</td>
<td>80.72</td>
<td>2.25</td>
</tr>
<tr>
<td>Expository Pause^b,c</td>
<td>8</td>
<td>84.12</td>
<td>502.00</td>
<td>4.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.64</td>
<td>76.69</td>
<td>2.25</td>
</tr>
<tr>
<td>Question Pause^b</td>
<td>13</td>
<td>79.54</td>
<td>464.38</td>
<td>4.85</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.88</td>
<td>78.93</td>
<td>2.23</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>Degrees Freedom</th>
<th>Mean Sum Squares</th>
<th>F</th>
<th>p &lt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within Cells</td>
<td>1611.97</td>
<td>59</td>
<td>27.32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regression</td>
<td>144.77</td>
<td>2</td>
<td>72.38</td>
<td>2.65</td>
<td>.08</td>
</tr>
<tr>
<td>Treatment</td>
<td>369.37</td>
<td>3</td>
<td>123.12</td>
<td>4.51</td>
<td>.01d</td>
</tr>
</tbody>
</table>

^aCovariates Scholastic Aptitude Test-Verbal and Insect pretest are used.

^b_t-test comparison of response score means of Expository Pause and Question Pause groups: Difference of means = 4.58, t = 1.88, p < .10 (two-tailed test) n.s.d.

^c_t-test comparison of response score means of No Pause and Expository Pause groups. Difference of means = 6.35, t = 2.64, p < .02 (two-tailed test).

^dEstimated \( \omega^2 = .13 \).

The follow-up t-tests in Table 9 suggest that the Expository Pause group is favored in the case of the response score, significantly so when compared to the No Pause group; conclusions drawn from this outcome must be qualified however, since these two groups are a bit uneven in number and were not drawn from the same population group.
### TABLE 10. — One-way analysis of variance with four treatments on Insect lesson effectiveness in immediate posttest

<table>
<thead>
<tr>
<th>Treatment</th>
<th>No. of Cases</th>
<th>Immediate Posttest</th>
<th>SAT-VA</th>
<th>Insect PretestA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Means and Standard Deviations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full Pause</td>
<td>22</td>
<td>62.91 10.43</td>
<td>464.77</td>
<td>4.82</td>
</tr>
<tr>
<td>No Pause</td>
<td>22</td>
<td>59.82 9.52</td>
<td>460.50</td>
<td>5.14</td>
</tr>
<tr>
<td>Expository Pause</td>
<td>8</td>
<td>61.75 10.95</td>
<td>502.00</td>
<td>4.25</td>
</tr>
<tr>
<td>Question Pause</td>
<td>13</td>
<td>64.31 6.51</td>
<td>464.38</td>
<td>4.85</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>Degrees Freedom</th>
<th>Mean Sum Squares</th>
<th>F</th>
<th>p&lt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within Cells</td>
<td>3710.27</td>
<td>59</td>
<td>62.89</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regression</td>
<td>1035.09</td>
<td>2</td>
<td>517.54</td>
<td>8.23</td>
<td>.001</td>
</tr>
<tr>
<td>Treatment</td>
<td>210.72</td>
<td>3</td>
<td>70.24</td>
<td>1.12</td>
<td>.350</td>
</tr>
</tbody>
</table>

aCovariates Scholastic Aptitude Test-Verbal and Insect pretest are used.

### TABLE 11. — One-way analysis of variance with four treatments on Insect lesson effectiveness in delayed posttest

<table>
<thead>
<tr>
<th>Treatment</th>
<th>No. of Cases</th>
<th>Delayed Posttest</th>
<th>SAT-VA</th>
<th>Insect PretestA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Means and Standard Deviations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full Pause</td>
<td>21</td>
<td>30.95 10.33</td>
<td>464.29</td>
<td>4.90</td>
</tr>
<tr>
<td>No Pause</td>
<td>20</td>
<td>33.00 9.18</td>
<td>466.55</td>
<td>5.05</td>
</tr>
<tr>
<td>Expository Pause</td>
<td>8</td>
<td>34.00 10.24</td>
<td>502.00</td>
<td>4.25</td>
</tr>
<tr>
<td>Question Pause</td>
<td>13</td>
<td>32.62 6.96</td>
<td>464.38</td>
<td>4.85</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>Degrees Freedom</th>
<th>Mean Sum Squares</th>
<th>F</th>
<th>p&lt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within Cells</td>
<td>3629.30</td>
<td>56</td>
<td>64.81</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regression</td>
<td>1420.73</td>
<td>2</td>
<td>710.36</td>
<td>10.96</td>
<td>.001</td>
</tr>
<tr>
<td>Treatment</td>
<td>59.10</td>
<td>3</td>
<td>19.70</td>
<td>3.30</td>
<td>—</td>
</tr>
</tbody>
</table>

aCovariates Scholastic Aptitude Test-Verbal and Insect pretest are used.
The four-treatment analysis of variance, with covariates, would show that again it is in the response score criterion that the treatment effect is most critical. Here the null hypothesis (four) is rejected at the .01 level and the estimated strength of association is .13.

The difference in means between the Expository Pause and Question Pause groups on the response scores, while not statistically significant, nevertheless suggests that the additional time allowance at the response point in the lesson is not a strong determiner of success in program performance when verbal content is used.

The four-treatment group analysis reveals no statistically significant treatment effects occurring when criteria are the two measures of learning effectiveness. The loss of cases for whom Scholastic Aptitude Test scores were unavailable accounts for the discrepancy of means reported in Tables 3, 4 and 5 contrasted to those in Tables 9, 10 and 11 for the Full Pause and No Pause groups.

The next seven tables (12-18) do not present data specifically directed toward the test of any hypothesis but rather are intended to supplement the data pertaining to the verbal content lessons. Tables 12 and 13 examine the homogeneity of the four treatment groups based on the independent variables, Scholastic Aptitude Test-Verbal and Insect pretest.
TABLE 12.—Test for homogeneity of four treatment groups using Scholastic Aptitude Test-Verbal as criterion

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of Cases</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Pause</td>
<td>22</td>
<td>464.77</td>
<td>73.58</td>
</tr>
<tr>
<td>No Pause</td>
<td>22</td>
<td>460.50</td>
<td>80.72</td>
</tr>
<tr>
<td>Expository Pause</td>
<td>8</td>
<td>502.00</td>
<td>76.69</td>
</tr>
<tr>
<td>Question Pause</td>
<td>13</td>
<td>464.38</td>
<td>78.93</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>Degrees of Freedom</th>
<th>Mean Squares</th>
<th>F</th>
<th>p&lt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within Cells</td>
<td>366484.69</td>
<td>61</td>
<td>6007.95</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment Groups</td>
<td>10882.67</td>
<td>3</td>
<td>3627.56</td>
<td>0.604</td>
<td></td>
</tr>
</tbody>
</table>

TABLE 13.—Test for homogeneity of four treatment groups using Insect pretest as criterion

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of Cases</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Pause</td>
<td>27</td>
<td>4.82</td>
<td>3.10</td>
</tr>
<tr>
<td>No Pause</td>
<td>23</td>
<td>4.96</td>
<td>2.36</td>
</tr>
<tr>
<td>Expository Pause</td>
<td>11</td>
<td>4.09</td>
<td>1.92</td>
</tr>
<tr>
<td>Question Pause</td>
<td>16</td>
<td>4.56</td>
<td>2.28</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>Degrees of Freedom</th>
<th>Mean Squares</th>
<th>F</th>
<th>p&lt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within Cells</td>
<td>487.88</td>
<td>73</td>
<td>6.68</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment Groups</td>
<td>6.25</td>
<td>3</td>
<td>2.08</td>
<td>0.312</td>
<td></td>
</tr>
</tbody>
</table>

The above two tables indicate that from a statistical standpoint there are no apparent differences in the four groups in regard to the two independent criteria. The F ratios both would indicate that there is at least as much variance within as between groups.
Related to the above are the data of Table 14 which gives correlations between the immediate posttest criterion and each of the above two scores. Also, the Scholastic Aptitude Test-Mathematical score is included for comparison purposes.

TABLE 14.—Correlation between Insect immediate posttest and the independent criteria, Scholastic Aptitude Tests, Verbal (SAT-V) and Mathematical (SAT-M) and Insect pretest

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Number of Cases</th>
<th>r</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAT-V</td>
<td>62</td>
<td>.452</td>
<td>.001</td>
</tr>
<tr>
<td>SAT-M</td>
<td>62</td>
<td>.352</td>
<td>.010</td>
</tr>
<tr>
<td>Insect Pretest</td>
<td>62</td>
<td>.278</td>
<td>.050</td>
</tr>
</tbody>
</table>

Cases for whom complete scores are available in all four treatment groups were used. Last column indicates probability level that r does not differ from zero.

The greater weight displayed by the Scholastic Aptitude Test-Verbal score provides some measure of justification for its choice as the aptitude variable used in conjunction with the test of hypotheses two and three.

The following table compares two groups of learners, (1) those who were in the original selection by random number assignment, and who completed the response sheet and immediate posttest for just part one of the lesson and (2) that subgroup of the above who attended both lesson sessions. Because the treatment group comparison seems most critical between the Full Pause and No Pause groups in the Immediate posttest (see Table 4) it is with these two that the comparison is made. The following reasoning is applied here: In the assumption
that the treatment effects are real and will create approximately the same average differential per item on the two test parts between groups, the proportions, or percentages, that the difference in means comprises of the total number of test items should be the same for part one and for the total. Hence the 5.22 raw score difference out of 75 possible items on the total test is the basis for the 6.95 percent that appears in the lower right portion of Table 15. If the two percentages corresponding to part one and total are comparable, then the above assumptions would appear reasonably well justified.

TABLE 15.—Test on effect of learner attrition after taking Part One of Insects immediate posttest—Full Pause and No Pause groups Only

<table>
<thead>
<tr>
<th>Group</th>
<th>Part One</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Cases</td>
<td>Mean</td>
</tr>
<tr>
<td>Full Pause</td>
<td>31</td>
<td>30.38</td>
</tr>
<tr>
<td>No Pause</td>
<td>32</td>
<td>27.75</td>
</tr>
<tr>
<td>Difference in means</td>
<td>2.63</td>
<td></td>
</tr>
<tr>
<td>% difference in means of total test item number</td>
<td>6.75%</td>
<td></td>
</tr>
</tbody>
</table>

The purpose of the above comparison is to be able to make some judgment as to how the dropout of cases between Parts I and II of the lesson may have affected the total mean scores for each treatment group. As the table indicates, the Full Pause and No Pause groups started with 31 and 32 and finished with 27 and 24, respectively; the Full Pause group is obviously favored here in both means. That the percentage of
mean difference out of the total test items is slightly greater in the total score might suggest the possibility of the attrition effect favoring the Full Pause group. If, however, the same percentage difference in means from part one were projected to the total score, then the latter raw score difference would be closer to 5.06 rather than 5.22 (Table 4). If too, the final variances could yet be assumed with the original number of cases, a recomputed t ratio using this adjusted raw difference would become 2.18 which is a one-tail test of mean differences is yet above the p .025 level of significance. This would seem to lend support to the claim that the treatment effect on this particular criterion is indeed real.

Tables 16 and 17 present comparative data on the immediate posttest and delayed posttest. Specifically, those items that were used on both instruments are being examined in the two treatment groups, Full Pause and No Pause.

TABLE 16—Item difficulty for delayed posttest and immediate posttest, both administered in immediate posttest context—Full Pause and No Pause groups, Insects

<table>
<thead>
<tr>
<th>Group</th>
<th>% Missed, Immediate Posttest (75 items)</th>
<th>% Missed, Delayed Posttest Items When Used in Immediate Posttest (50 items)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Pause</td>
<td>14.5%</td>
<td>15.0%</td>
</tr>
<tr>
<td>No Pause</td>
<td>21.3%</td>
<td>20.7%</td>
</tr>
</tbody>
</table>

The percentage difficulty of the 50-item test to that of the 75 items and the inter-treatment group difference seems reasonably well maintained.
The next table contrasts the actual delayed posttest results in percentage correct to what was achieved on the same set of items in the immediate posttest setting. As has already been indicated in Tables 5, 8 and 11, the treatment effect differences are not evident seven days after instruction.

TABLE 17.—Actual delayed posttest scores and score of same items on immediate posttest, Insects

<table>
<thead>
<tr>
<th>Group</th>
<th>% Correct of 50 Items in Immediate Posttest</th>
<th>% Correct of 50 Items in Delayed Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Pause</td>
<td>85.0%</td>
<td>64%</td>
</tr>
<tr>
<td>No Pause</td>
<td>79.3%</td>
<td>66%</td>
</tr>
</tbody>
</table>

The information in the above table is an indicator of the amount of forgetting that occurred over the seven-day delay interval after instruction.

Presented in the next table is a comparable analysis between percentage means on the same twenty-two pretest items when taken in both the pretest and immediate posttest context.

TABLE 18.—Actual pretest scores and score of same items on immediate posttest, Insects

<table>
<thead>
<tr>
<th>Group</th>
<th>% Correct of 22 Items in Immediate Posttest</th>
<th>% Correct of 22 Items in Pretest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Pause</td>
<td>92%</td>
<td>24%</td>
</tr>
<tr>
<td>No Pause</td>
<td>84%</td>
<td>24%</td>
</tr>
</tbody>
</table>
This result would suggest that regardless of which treatment group is involved, the instruction does yield a considerable gain in learning.

Simple Machine Lesson Data

The same organization of data tables and discussion will be used in this section as was done in the one preceding.

Tables 19, 20 and 21: Test of Hypothesis One.—The hypothesis reads:

1. An increase in learning time will not significantly result in an increase of either of the dependent variables, learning performance and effectiveness.

| TABLE 19.—t-test comparison of Full Pause and No Pause groups on Simple Machines lesson program learning performance (response scores) |
|---|---|---|
| Group | Number of Cases | Mean | Standard Deviation |
| Full Pause | 29 | 42.86 | 5.27 |
| No Pause | 25 | 36.48 | 6.22 |

Note: Difference in means = 6.38, \( t = 3.99 \), \( p < .001 \) (one tail), estimated \( \omega^2 = .22 \).

| TABLE 20.—t-test comparison of Full Pause and No Pause groups on Simple Machines lesson program learning effectiveness in immediate posttest |
|---|---|---|
| Group | Number of Cases | Mean | Standard Deviation |
| Full Pause | 29 | 30.41 | 8.34 |
| No Pause | 25 | 25.52 | 9.56 |

Note: Difference in means = 4.89, \( t = 1.97 \), \( p < .05 \) (one tail), estimated \( \omega^2 = .05 \).
TABLE 21.—t-test comparison of Full Pause and No Pause groups on Simple Machines lesson program learning effectiveness in delayed posttest

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of Cases</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Pause</td>
<td>25</td>
<td>16.44</td>
<td>5.98</td>
</tr>
<tr>
<td>No Pause</td>
<td>22</td>
<td>15.00</td>
<td>6.84</td>
</tr>
</tbody>
</table>

Note: Difference in means = 1.44, t = .75, p < .25 (n.s.d. in one tail test).

The treatment effect is again, as in the previous section, most evident on the program performance. Null hypothesis one was rejected at the p < .001 level with an estimated strength of association computed at .22 when using this criterion.

Null hypothesis one is rejected at the p < .05 level when the Immediate posttest score is the criterion. Estimated strength of association is .05.

No observable difference between groups was noted on the delayed posttest.

Tables 22, 23 and 24: Test of Hypotheses Two and Three.—The hypotheses read:

2. Learner aptitude will have no significant effect on either of the dependent variables, learning performance and effectiveness.

3. There will be no significant interaction between learning time and learner aptitude as they effect either of the dependent variables, learning performance and effectiveness.
Learner Scholastic Aptitude Test-Mathematical (SAT-M) scores were the basis for aptitude level assignments. The placement within aptitude levels was determined by the following scale:

- **High level** — SAT-M score above 508
- **Middle Level** — SAT-M score included in 462-508 range
- **Low level** — SAT-M score below 462

A two-way, 3 x 2 analysis of variance was applied which gave a reading on both hypotheses in question.

**TABLE 22.— 3 x 2 Scholastic Aptitude Test-Mathematical levels by treatments, analysis of variance of Simple Machines lesson program learning performance (response scores)**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Level</th>
<th>Population</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Pause</td>
<td>High</td>
<td>7</td>
<td>43.86</td>
<td>5.82</td>
</tr>
<tr>
<td>Full Pause</td>
<td>Middle</td>
<td>9</td>
<td>42.67</td>
<td>1.66</td>
</tr>
<tr>
<td>Full Pause</td>
<td>Low</td>
<td>9</td>
<td>41.56</td>
<td>7.38</td>
</tr>
<tr>
<td>No Pause</td>
<td>High</td>
<td>7</td>
<td>40.71</td>
<td>4.64</td>
</tr>
<tr>
<td>No Pause</td>
<td>Middle</td>
<td>8</td>
<td>34.62</td>
<td>6.12</td>
</tr>
<tr>
<td>No Pause</td>
<td>Low</td>
<td>5</td>
<td>34.80</td>
<td>7.98</td>
</tr>
</tbody>
</table>

**Source**

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>Degrees Freedom</th>
<th>Mean Sum of Squares</th>
<th>F</th>
<th>p &lt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within Cells</td>
<td>1307.18</td>
<td>39</td>
<td>33.52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatments (T)</td>
<td>373.78</td>
<td>1</td>
<td>373.78</td>
<td>11.15</td>
<td>.002</td>
</tr>
<tr>
<td>Aptitude (A)</td>
<td>138.06</td>
<td>2</td>
<td>69.03</td>
<td>2.06</td>
<td>.140</td>
</tr>
<tr>
<td>T x A</td>
<td>47.95</td>
<td>2</td>
<td>23.98</td>
<td>.72</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1867.97</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The treatment effect strength is evident again as it was in Table 19. The aptitude and interaction effects are not significant although a hint of a trend is evident as Figure 5 suggests.
Fig. 5.—Program response score means plotted against aptitude level for each treatment, Full Pause and No Pause, Simple Machines lesson.

Table 23 and Figure 6 show a comparable result for the Immediate posttest scores as was observed for the response score, where an even larger aptitude and interaction trend is suggested, but yet not sufficient to reject the hypotheses.

TABLE 23.—3 x 2, Scholastic Aptitude Test-Mathematical levels by treatments, analysis of variance of Simple Machines lesson program learning effectiveness in immediate posttest

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Level</th>
<th>Population</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Pause</td>
<td>High</td>
<td>7</td>
<td>31.86</td>
<td>9.00</td>
</tr>
<tr>
<td>Full Pause</td>
<td>Middle</td>
<td>9</td>
<td>31.00</td>
<td>7.05</td>
</tr>
<tr>
<td>Full Pause</td>
<td>Low</td>
<td>9</td>
<td>29.78</td>
<td>9.90</td>
</tr>
<tr>
<td>No Pause</td>
<td>High</td>
<td>7</td>
<td>32.14</td>
<td>6.89</td>
</tr>
<tr>
<td>No Pause</td>
<td>Middle</td>
<td>9</td>
<td>21.12</td>
<td>7.55</td>
</tr>
<tr>
<td>No Pause</td>
<td>Low</td>
<td>5</td>
<td>21.40</td>
<td>13.61</td>
</tr>
</tbody>
</table>
### TABLE 23—Continued

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>Degrees Freedom</th>
<th>Mean Sum Squares</th>
<th>F</th>
<th>p&lt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within Cells</td>
<td>3093.34</td>
<td>39</td>
<td>79.32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatments (T)</td>
<td>367.36</td>
<td>1</td>
<td>367.36</td>
<td>4.63</td>
<td>.038</td>
</tr>
<tr>
<td>Aptitude (A)</td>
<td>339.93</td>
<td>2</td>
<td>169.97</td>
<td>2.14</td>
<td>.131</td>
</tr>
<tr>
<td>T x A</td>
<td>219.67</td>
<td>2</td>
<td>109.84</td>
<td>1.38</td>
<td>.262</td>
</tr>
<tr>
<td>Total</td>
<td>4020.30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 6.** Immediate posttest score means plotted against aptitude level for each treatment, Full Pause and No Pause, Simple Machines lesson.

Table 24 and Figure 7 show the results of the delayed posttest analysis. No effects are sufficient to reject either of the null hypotheses although aptitude does show the possibility of influence.
TABLE 24.--3 x 2, Scholastic Aptitude Test-Mathematical levels by treatments, analysis of variance of Simple Machines lesson program learning effectiveness in delayed posttest

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Level</th>
<th>Population</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Pause</td>
<td>High</td>
<td>5</td>
<td>18.60</td>
<td>5.18</td>
</tr>
<tr>
<td>Full Pause</td>
<td>Middle</td>
<td>9</td>
<td>16.22</td>
<td>5.07</td>
</tr>
<tr>
<td>Full Pause</td>
<td>Low</td>
<td>8</td>
<td>15.00</td>
<td>7.54</td>
</tr>
<tr>
<td>No Pause</td>
<td>High</td>
<td>5</td>
<td>20.40</td>
<td>4.28</td>
</tr>
<tr>
<td>No Pause</td>
<td>Middle</td>
<td>8</td>
<td>11.88</td>
<td>6.42</td>
</tr>
<tr>
<td>No Pause</td>
<td>Low</td>
<td>4</td>
<td>14.50</td>
<td>9.88</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>Degrees Freedom</th>
<th>Mean Sum Squares</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within Cells</td>
<td>1365.83</td>
<td>33</td>
<td>41.39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatments (T)</td>
<td>16.66</td>
<td>1</td>
<td>16.66</td>
<td>.403</td>
<td></td>
</tr>
<tr>
<td>Aptitude (A)</td>
<td>200.85</td>
<td>2</td>
<td>100.43</td>
<td>2.430</td>
<td>.104</td>
</tr>
<tr>
<td>T x A</td>
<td>64.09</td>
<td>2</td>
<td>32.04</td>
<td>.774</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1647.43</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)Estimated \(\omega^2\) (criterion with aptitude) = .07.

Fig. 7.—Delayed posttest score means plotted against aptitude level for each treatment, Full Pause and No Pause, Simple Machines lesson.
Tables 25, 26 and 27: Test of Hypothesis Four.—The hypothesis reads:

4. A variation in the placement of pause intervals within the programmed lesson will not significantly effect either of the dependent variables, learning performance and effectiveness.

TABLE 25.—One-way analysis of variance with four treatments of Simple Machines lesson performance (response score)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>No. of Cases</th>
<th>Response Scores Mean</th>
<th>SAT-M (^a)</th>
<th>Math Skills Pretest (^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Pause (^d)</td>
<td>24</td>
<td>42.50</td>
<td>480.42</td>
<td>9.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.42</td>
<td>58.78</td>
<td>.72</td>
</tr>
<tr>
<td>No Pause (^e)</td>
<td>20</td>
<td>36.80</td>
<td>496.50</td>
<td>8.80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.53</td>
<td>62.50</td>
<td>1.10</td>
</tr>
<tr>
<td>Expository Pause (^c,d)</td>
<td>10</td>
<td>37.00</td>
<td>513.40</td>
<td>8.80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.67</td>
<td>90.66</td>
<td>1.14</td>
</tr>
<tr>
<td>Question Pause (^c,e)</td>
<td>12</td>
<td>43.67</td>
<td>534.25</td>
<td>9.08</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.09</td>
<td>57.09</td>
<td>1.08</td>
</tr>
</tbody>
</table>

Source

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>Degrees Freedom</th>
<th>Mean Sum Squares</th>
<th>F</th>
<th>p &lt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within Cells</td>
<td>1977.63</td>
<td>60</td>
<td>32.96</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regression</td>
<td>324.24</td>
<td>2</td>
<td>162.12</td>
<td>4.92</td>
<td>.011</td>
</tr>
<tr>
<td>Treatments</td>
<td>457.75</td>
<td>33</td>
<td>152.58</td>
<td>4.63</td>
<td>.006(^b)</td>
</tr>
<tr>
<td>Total</td>
<td>2759.62</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)Covariates Scholastic Aptitude Test—Mathematical and Math Skills pretest are used.

\(^b\)Estimated \(\omega^2\) (criterion with treatments) = .09.

\(^c\)t-test comparison of response score means of Expository Pause and Question Pause groups. Difference of means = 6.67, \(t = 2.32\), \(p < .05\) (two-tailed test).

\(^d\)t-test comparison of response score means of Full Pause and Expository Pause groups. Difference of means = 4.50, \(t = 1.88\), \(p < .10\) (n.s.d. in two-tail test).

\(^e\)t-test comparison of response score means of Question Pause and No Pause groups. Difference of means = 6.87, \(t = 3.02\), \(p < .01\) (in two-tail test).
TABLE 26.—One-way analysis of variance with four treatments of Simple Machines lesson effectiveness in immediate posttest

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of Cases</th>
<th>Immediate Posttest Scores</th>
<th>SAT-M Pretesta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Pause</td>
<td>24</td>
<td>30.58, 8.49</td>
<td>9.50, .72</td>
</tr>
<tr>
<td>No Pause</td>
<td>20</td>
<td>25.05, 10.16</td>
<td>8.80, 1.10</td>
</tr>
<tr>
<td>Expository Pause</td>
<td>10</td>
<td>27.80, 10.90</td>
<td>8.80, 1.14</td>
</tr>
<tr>
<td>Question Pause</td>
<td>12</td>
<td>33.58, 5.85</td>
<td>9.08, 1.08</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>Degrees of Freedom</th>
<th>Mean Sum Squares</th>
<th>F</th>
<th>p &lt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within Cells</td>
<td>4319.57</td>
<td>60</td>
<td>71.99</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regression</td>
<td>751.74</td>
<td>2</td>
<td>375.87</td>
<td>5.22</td>
<td>.008</td>
</tr>
<tr>
<td>Treatments</td>
<td>385.96</td>
<td>3</td>
<td>128.66</td>
<td>1.79</td>
<td>.159</td>
</tr>
</tbody>
</table>

*Covariates Scholastic Aptitude Test-Mathematical and Math Skills pretest are used.

TABLE 27.—One-way analysis of variance with four treatments of Simple Machines lesson effectiveness in delayed posttest

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of Cases</th>
<th>Delayed Posttest</th>
<th>SAT-M Pretesta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Pause</td>
<td>22</td>
<td>16.32, 5.98</td>
<td>9.46, .74</td>
</tr>
<tr>
<td>No Pause</td>
<td>17</td>
<td>15.00, 7.42</td>
<td>8.65, 1.11</td>
</tr>
<tr>
<td>Expository Pause</td>
<td>9</td>
<td>15.00, 7.45</td>
<td>8.67, 1.12</td>
</tr>
<tr>
<td>Question Pause</td>
<td>10</td>
<td>19.50, 3.50</td>
<td>9.10, 1.10</td>
</tr>
</tbody>
</table>

*Covariates Scholastic Aptitude Test-Mathematical and Math Skills pretest are used.
No treatment effects are apparent with regard to the remaining two criteria in the test of hypothesis four. The discrepancy in mean scores between the two sets of tables (17, 18, 19 and 23, 24, 25) is accounted for by the loss of cases for whom no SAT score was available.

The remaining six tables (26-31) are intended as supplements to the data from the mathematical content lessons.

**TABLE 28.**—Test for homogeneity of four treatment groups using Scholastic Aptitude Test-Mathematical as criterion

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of Cases</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Pause</td>
<td>25</td>
<td>484.40</td>
<td>58.39</td>
</tr>
<tr>
<td>No Pause</td>
<td>20</td>
<td>496.50</td>
<td>62.50</td>
</tr>
<tr>
<td>Expository Pause</td>
<td>10</td>
<td>513.40</td>
<td>90.66</td>
</tr>
<tr>
<td>Question Pause</td>
<td>12</td>
<td>534.25</td>
<td>57.09</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>Degrees Freedom</th>
<th>Mean Squares</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within Cells</td>
<td>265,875.06</td>
<td>63</td>
<td>4220.24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment Groups</td>
<td>238,431.12</td>
<td>3</td>
<td>7947.71</td>
<td>1.88</td>
<td>.141</td>
</tr>
</tbody>
</table>
TABLE 29.—Test for homogeneity of four treatment groups using Math Skills pretest as criterion

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of Cases</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Pause</td>
<td>28</td>
<td>9.39</td>
<td>.83</td>
</tr>
<tr>
<td>No Pause</td>
<td>24</td>
<td>8.75</td>
<td>1.03</td>
</tr>
<tr>
<td>Expository Pause</td>
<td>13</td>
<td>9.00</td>
<td>1.08</td>
</tr>
<tr>
<td>Question Pause</td>
<td>16</td>
<td>9.00</td>
<td>1.10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>Degrees Freedom</th>
<th>Mean Square</th>
<th>F</th>
<th>p&lt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within Cells</td>
<td>75.18</td>
<td>77</td>
<td>.98</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment Groups</td>
<td>5.51</td>
<td>3</td>
<td>1.84</td>
<td>1.88</td>
<td>.140</td>
</tr>
</tbody>
</table>

A cursory inspection of the Scholastic Aptitude Test-Mathematical score means might suggest that the Question Pause group here is slightly favored. However, as Table 27 indicates, there is no statistically significant variation between the four treatment groups on this criterion. The same holds true for the pretest.

TABLE 30.—Correlation between Simple Machine immediate posttest and the independent criteria, Scholastic Aptitude Test-Mathematical (SAT-M) and Math Skills pretest

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Number of Cases</th>
<th>r</th>
<th>p&lt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAT-M</td>
<td>66</td>
<td>.349</td>
<td>.01</td>
</tr>
<tr>
<td>SAT-V</td>
<td>66</td>
<td>.227</td>
<td>.10</td>
</tr>
<tr>
<td>Math Skills</td>
<td>66</td>
<td>.285</td>
<td>.05</td>
</tr>
</tbody>
</table>

aCases for whom complete scores are available in all four treatment groups were used. Last column indicates probability level that r does not differ from zero.
TABLE 31.—Test on effect of learner attrition after taking part one of Simple Machines immediate posttest—Full Pause and No Pause groups only

<table>
<thead>
<tr>
<th>Group</th>
<th>Part One</th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Cases</td>
<td>Mean</td>
<td>No. Test Items</td>
</tr>
<tr>
<td>Full Pause</td>
<td>34</td>
<td>16.00</td>
<td>20</td>
</tr>
<tr>
<td>No Pause</td>
<td>28</td>
<td>13.64</td>
<td>20</td>
</tr>
</tbody>
</table>

Difference in means
2.36

% difference in means of total test item number
11.80%

The slight percentage increase of mean difference from part one to total posttest score suggests that, as in the case of the verbal content analysis of Table 15, if the attrition of cases had any effect, it would tend to favor the Full Pause group.

Tables 32 and 33 consider certain comparative features of the immediate posttest and the delayed posttest.

TABLE 32.—Comparison of item difficulty between delayed posttest and Immediate posttest when both are administered in immediate posttest context—Full Pause and No Pause groups are used for comparison across treatments, Simple Machines

<table>
<thead>
<tr>
<th>Group</th>
<th>% Missed, Immediate Posttest (39 items)</th>
<th>% Missed, Delayed Posttest Items When Used in Immediate Posttest (25 items)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Pause</td>
<td>22.0%</td>
<td>21.5%</td>
</tr>
<tr>
<td>No Pause</td>
<td>34.6%</td>
<td>37.9%</td>
</tr>
</tbody>
</table>
The percentage difficulty of the 25-item test to that of the 39 items and the inter-treatment group difference seems reasonably constant. The next table gives actual delayed posttest results in percentage correct contrasted to what was achieved on the same set of items in the immediate posttest setting.

TABLE 33.—Comparison of actual delayed posttest scores to score of same items on immediate posttest, Simple Machines

<table>
<thead>
<tr>
<th>Group</th>
<th>% Correct, Immediate Posttest (25 items)</th>
<th>% Correct of Delayed Posttest (25 items)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Pause</td>
<td>78.5%</td>
<td>65.8%</td>
</tr>
<tr>
<td>No Pause</td>
<td>62.1%</td>
<td>60.0%</td>
</tr>
</tbody>
</table>

One interesting facet of the above comparison is that the No Pause group showed relatively little forgetting of the content over the five-day interval.

Summary: Data Analysis

Certain characteristics common to both content types are evident in the data analysis. Most notable is the rejection of hypothesis one in the program lesson performance criterion at a rather high level of significance ($p < .001$ for both) and relatively high estimated $\omega^2$s (.20 and .22).

Hypothesis one is rejected again in both instances using the Immediate posttest but at a decidedly lower significance level ($p < .025$ and $p < .05$) and with smaller $\omega^2$s (.06 and .05).
Results from the delayed posttest criterion indicate that treatment effects are not apparent when using either content type.

Hypothesis four is rejected in the instance of program lesson performance with both content types. A look at mean score comparisons between individual groups would suggest that the added pause at the expository point tends to enhance criterion scores with verbal content, while the added pause at response points is more instrumental in the case of mathematical content.

The aptitude levels factor is sufficiently strong to warrant rejection of hypothesis two only in the instance of the immediate posttest using verbal content ($p < .05$ and estimated $\omega^2 = .09$). Relevant to this consideration is the data presented in the supplementary Tables 14 and 30 showing correlations between aptitude and immediate posttest scores.
CHAPTER VI

SUMMARY, IMPLICATIONS AND RECOMMENDATIONS

This concluding chapter consists of four main sections. First, a summary of the entire study will be offered; second, a statement of the delimitations and limitations of the study; third, a discussion of the implications and interpretation of the results; and fourth, final recommendations and a conclusion.

Summary of the Study

Two programmed lessons, each of a different content type, were developed and adapted to video tape. Production of the tape was accomplished by playing back a previously recorded audio taped narrative of the lesson while the appropriate visual cues in the form of key words, sketches, or formula were displayed before the camera. The lessons were made at four different pace versions, each variation determined by the placement of additional pauses. The fastest pace, labeled the No Pause version proceeded at a regular narrative rate of speaking with just sufficient time pause allowance for learners to write out responses to questions posed during the lesson. A Question Pause version utilized the same narrative tape as the preceding one except that additional pause time was inserted at those places where learner responses were required; and Expository Pause version had additional pause time inserted at key points within the expository lesson passages.
The fourth version, called Full Pause, consumed almost twice the time as the No Pause version and was constructed by inserting additional pause time at both the response points and key expository points.

The study was motivated by the prospect of utilizing video tape as the medium for the presentation of programmed instruction. Such a union, it was assumed, would require that the pace of instruction be externally determined, placing it outside the control of the individual learner. It was the possible influence of a varying learning pace, along with its possible interaction with learner aptitude, that was chosen as the main point of interest in the study.

The two lesson topics were chosen because of each being representative of a particular content type. One of these, a lesson on Insects, was characterized as requiring more of a learner's verbal aptitude, while the other, a lesson on Simple Machines, called more upon mathematical skills.

Subjects were taken from enrollees in a college class, Science for Elementary Teachers, to form four treatment groups, each corresponding to a given pace version. Each lesson was organized into two segments which were presented on successive class meeting days. The study criteria were three: (1) response score made by the learner to questions posed during the lesson presentation, (2) posttest score over content taken immediately after a lesson segment was completed, and (3) delayed posttest score from testing over content taken five to seven days after the final segment of instruction.
The following four null hypotheses define the essence of the study:

1. An increase in learning time will not significantly result in an increase of either of the dependent variables, learning performance and effectiveness.

2. Learner aptitude will have no significant effect on either of the dependent variables, learning performance and effectiveness.

3. There will be no significant interaction between learning time and learner aptitude as they affect either of the dependent variables, learning performance and effectiveness.

4. A variation in the placement of pause intervals within the programmed lesson will not significantly affect either of the dependent variables, learning performance and effectiveness.

A one-tailed t-test comparison between the Full Pause and No Pause groups, representing the extremes in pace versions, was the method used for examining the first of these hypotheses. The first hypothesis was rejected in the following circumstances: (1) on response scores in both lessons at the $p < .001$ level; (2) on immediate posttest, verbal and mathematical content, at the $p < .025$ and $p < .05$ levels, respectively. The Full Pause group was thus favored on both criteria. No differences were apparent on the delayed posttest.

The second and third hypotheses were examined using a $3 \times 2$ aptitude levels by pace treatment two-way analysis of variance. Scholastic Aptitude Test scores were the basis of the three aptitude levels, identified as high, middle or low. The verbal portion of the score was used in conjunction with the Insect lesson analysis and the mathematical with that for Simple Machines. The Full Pause and No Pause groups constituted the treatment levels.
The second hypothesis was rejected in only one instance, that being at the $p < .05$ level on the immediate posttest from the verbal content lesson with the higher level aptitude levels generally favored.

The third hypothesis was prompted by the anticipation that a faster pace set for the instruction would call upon more of the learner's aptitude than at a slower pace; such an effect should show up as an interaction between aptitude levels and pace treatment. This trend, though observed in four instances with immediate posttest, verbal content, and with all three criteria from mathematical content, was not sufficiently pronounced to warrant rejection of the null hypothesis at the $p < .05$ level.

All four treatment groups were involved in the test of the last hypothesis where a one-way analysis of variance was used with mean scores adjusted with the covariates aptitude and pretest scores. The $F$ ratio was sufficient to warrant rejection of the null hypothesis when response score was the criterion for either content types ($p < .01$ with verbal and $p < .006$ with mathematical).

An estimated strength of association ($\omega^2$) which is a measure of the certainty that one variable can be used to predict another, was computed for pace treatment with criterion. A uniform trend was observed in both lessons where $\omega^2$ was highest with the response scores (.20 and .22), somewhat less for the immediate posttest (.06 and .05) and negligibly small on the delayed posttests.
Delimitations and Limitations of the Study

The generalizability of the results of the study is bounded by the following which may be best characterized as delimitations:

1. The pool of study subjects who participated consisted of college junior or senior elementary or special education majors at Madison College. The particular treatment or aptitude effects that have been noted in this study may not necessarily apply with other groups representing different levels of aptitudes, different degrees of heterogeneity in aptitude or different interest levels.

2. The particular set of pace rates and the methods for introducing pause intervals were governed primarily by the objective of obtaining an approximate 2:1 ratio in total lesson times between the two extreme paces. How similar the results might have been to those actually obtained were the ratio set differently or if an alternate pause interval method were used is a matter of conjecture.

3. Due to the nature of adapting programmed instruction to video tape, the method for controlling the time allowance (or pace) is determined by inserting pause intervals at specific points, this in contrast to those techniques using a single cue type, such as a visual or audio alone, which make the removal or addition of time somewhat simpler.

Conclusions drawn from the study must also be tempered because of the following factors which represent limitations:

1. The content of the two particular lessons, while specifically identified as either verbal or mathematical in type, cannot be claimed to represent all lessons of either of these two types.
The effect of the level of content sophistication within the lesson was a matter left untouched in this study.

2. No examination was made of the effect on study results by such factors as program step size in content, program density, mode of responding and other characteristics that pertain to program lesson strategy.

3. It was not possible to fulfill entirely the ideal conditions of a randomized selection of the subjects from a single population pool into treatment groups.

4. Further, as was discussed in Chapters IV and V, the treatment groups as selected did not remain entirely intact because of absences in the second session of each lesson or because of unavailability of aptitude scores for some.

5. The pretest, immediate posttests and delayed posttest were administered to all subjects in the study. The prospect thus of some test sensitization from the learner's prior exposure is evident. This may indeed be operative between the immediate and delayed posttests which were separated by a week or less.

Implications of the Data

As pointed out in the summary of the study given at the beginning of this chapter, hypothesis one is uniformly rejected in both content cases when criterion is response score. The results thus support the general contention that the provision of additional time in the externally paced programmed instruction enhances program
performance and is in accord with the findings of Gropper and Kress\textsuperscript{37} who found the pace treatment effect most pronounced on this measure.

Hypothesis one is also rejected in both instances when the criterion is immediate posttest score although significance level is decidedly less. It was on this measure however that Eckhardt\textsuperscript{38} observed the greater effect from pace variation.

An interesting contrast thus is noted between the two studies cited above. In one case the program performance seems most sensitive to pace treatment and in the other instance it is the immediate posttest score. The present study reported in these pages appears to be more in accord with the former if the comparative levels of significance at which the hypotheses were rejected were considered.

The trend exhibited by the results from Eckhardt's study seemingly are contrary to that of Gropper and Kress and the present study, as well as those of Green\textsuperscript{39} and Shay\textsuperscript{40} if one were to include other program strategy variables along with pace which seem to place comparable demands on the learner.

On the delayed posttests of the present study the pattern of decreasing strength of association between criterion and treatment effect is extended virtually to a negligible point. This entire trend is summarized in Table 34 and Figure 8 which accompanies the discussion.

\textsuperscript{37}Gropper and Kress, \textit{op. cit.}

\textsuperscript{38}Eckhardt, \textit{op. cit.}

\textsuperscript{39}Green, \textit{op. cit.}

\textsuperscript{40}Shay, \textit{op. cit.}
### TABLE 34.—Estimated strength of association of criterion variable when pace treatment effect on response score, immediate posttest and delayed posttest

<table>
<thead>
<tr>
<th>Content Type</th>
<th>Response Score</th>
<th>Immediate Posttest</th>
<th>Delayed Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal</td>
<td>.20</td>
<td>.06</td>
<td>_a</td>
</tr>
<tr>
<td>Mathematical</td>
<td>.22</td>
<td>.05</td>
<td>_a.</td>
</tr>
</tbody>
</table>

\(^a\)Treatment effect was statistically non-significant, hence \(\omega^2\) is assumed negligible.

![Graph](image)

**Fig. 8.**—Estimated strength of \(\omega^2\) with pace treatment effect for response score, immediate posttest and delayed posttest—both verbal and mathematical content types are plotted.
Foulke's delayed posttest data bear some similarity to this same pattern; however, the conditions of his study are notably different, namely in that the instruction was strictly by audio tape to blind subjects, was non-programmed, criterion instruments were multiple choice and the time delay interval was thirty days. He also attributed lack of difference in the thirty-day posttest scores between treatment groups to an almost complete forgetting of the content originally learned.

Some forgetting may have occurred in the present study to account for part of this leveling effect between groups but such does not seem a complete explanation. The data presented in Tables 17 (Insects) and 33 (Simple Machines) suggest that a substantial amount of content is retained (over 60 per cent correct in all cases) at the time of the delayed posttest.

The mechanism alluded to in number five of the limitations, where learners' prior experience with the immediate posttest may have contributed learning effects that positively influenced the delayed posttest score. Too, it is altogether likely that other unidentified and uncontrolled variables are operative in this five to seven-day interval.

This particular effect is germane to the question of how one designs a program strategy that would maximize learning effectiveness while taking into account time expenditure; this will be considered in such context in the section to follow.

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Foulke, op. cit., 1964.
A further observation may be noted in the standard deviation alongside the mean scores reported in Tables 3, 4, 5, 19, 20 and 21 where the two group comparisons were made. The smaller mean score is inevitably accompanied by the larger standard deviation. This result is in accord with Green's \(^{42}\) observation that a larger error rate on a program because of the content being more difficult or because of lower ability learners will be accompanied by a greater variance. The F ratio between these variances in the data reported will not be sufficiently large to substantiate a difference at the .05 level of significance.

**Aptitude.**—The aptitude-levels effect was sufficiently pronounced on only one criterion to warrant rejection of hypothesis two, this being the immediate posttest on verbal content. That it is evident here at the \(p < .05\) level and not on the corresponding test in the mathematical content is consistent with the correlation data of Tables 14 and 30 which show a coefficient of .452 (\(p < .01\)) for verbal immediate posttest with SAT-V contrasted to that of .349 (\(p < .01\)) for mathematical immediate posttest and SAT-M.

It would be imprudent to assume that since aptitude level effects are not strong enough to reject the null hypothesis on the other five criteria for which it was investigated, then somehow the particular program lesson and strategies were such as to be insensitive to aptitude. Such a conclusion would be counter to findings in all of

\(^{42}\)Green, op. cit., p. 170.
of the studies on external pacing where aptitude is a factor. On
the three mathematical lesson criteria (Tables 22, 23 and 24 and
Figures 5, 6 and 7) a trend suggesting the influence of aptitude is
noticeable in a scrutiny of the respective cell means. Surprising
however is the virtual lack of any such trend with respect to the
response score and delayed posttest score with verbal content when
it is most strongly supported on this immediate posttest. Because of
this inconsistency, it is difficult to infer that the nature of the
content is somehow a factor.

Lesson content difficulty, program step size and density,
variables which were uncontrolled in this study, may have had an
important hand in determining the measured strength of aptitude effect.
It would be anticipated that with a more difficult lesson content and
hence greater variance on criterion scores that aptitude effects would
be more pronounced.

Investigation for Interaction.—A similar pattern resulted in
the aptitude by treatments interaction effects as was observed for
aptitude alone. A tendency was observed in the expected direction in
the verbal immediate posttest and the three mathematical criteria
cases (Tables 7, 12, 23 and 24 and Figures 4, 5, 6 and 7, all of
Chapter V) but the analysis did not warrant rejection of the null
hypothesis. A comparable speculation is offered here with regard to
interaction effect as was suggested for aptitude alone, namely that
other uncontrolled variables would well be instrumental in determining
the statistical significance.

Gallegos, op. cit., and Eckhardt, op. cit.
The two similar studies in externally paced programmed instruction, those of Gallegos\textsuperscript{44} and Eckhardt\textsuperscript{45} where the same type of interaction effect was investigated, and in the latter case found statistically significant, used subject samples of 300 and 110, respectively, a number somewhat larger than was used in the present study. A reasonable inference is that if the observed but non-significant trends noted above with respect to aptitude effects alone and interaction effects are in fact real, then a larger subject sample would more likely have borne this out statistically.

\textbf{Pause Interval Placement.---}The test of null hypothesis four was motivated by an interest in being able to determine the relative importance of the two points at which pause intervals were placed in the programmed lesson. Hence, the chief source of interest is in the Expository Pause and Question Pause groups comparisons even though all four groups were involved in the analysis of variance. On the verbal response score the Expository Pause group is slightly favored while on the immediate posttest score, the opposite is observed, although in neither case is the $p < .05$ significance level attained in these differences (Tables 9 and 10).

In the mathematical content analysis the Question Pause group is favored on both response score and immediate posttest (Tables 25 and 26), in the first instance at the $p < .05$ level. An explanation for this consistent trend, if in fact real, could be offered in terms

\textsuperscript{44}Gallegos, op. cit.

\textsuperscript{45}Eckhardt, op. cit.
of the nature of the content and the lesson. Where the learner is called upon to perform a computational operation, as was the case here, the additional pause interval at the response point may indeed be necessary for contemplation of the concepts entailed, something that would likely not be as critical in the verbal content lesson where the simple recall of a word was generally involved.

Recommendations

The discussion in the preceding section raises two types of considerations which take the form of recommendation for further study or action. First are those of a more theoretical or research orientation nature and secondly, those of a developmental nature with more direct concern to educational field practices. Each will be considered separately in the following discussion.

Theoretical Considerations.—The hypothetical model, described in Chapter III and designed to apply to externally paced programmed instruction, takes into account only the two variables, aptitude and program pace. Such a model, if demonstrated to be feasible in a variety of externally paced programmed instruction contexts, could conceivably represent the cornerstone of a still larger and more comprehensive paradigm.

It is proposed that the original model be further examined in terms of establishing those extreme paces, labeled $a$ and $d$ as in the figure below. Is there an optimum pace $d$ at which all slower rates will produce a decrease on the learning criterion?
The more extensive model proposed would deal with at least two other variables in addition to (1) aptitude and (2) pace rate. These variables suggested are (3) lesson step size and (4) content difficulty. Each of these paired with another would imply a research study comparable to that described in these pages. Were a sufficiently large subject pool available, a three-way factorial analysis design might prove feasible.

It was suggested for instance in the preceding section that aptitude may be a more significant variable when lesson content is more difficult. If true, this would manifest itself as an interaction effect.

Each of these four variables identified in the model can be operationally defined in terms of a quantitative scale. More difficult is the notion of content type. If the model envisioned were to be ultimately useful, its generalizability would necessarily have to be demonstrated in a variety of content type contexts.
Developmental Considerations.—Realistically, the prospects for a full scale testing and validation of the model alluded to above would be most likely after externally paced programmed instruction were a generally accepted mode of instruction in the educational field setting. The results of the study provoke some questions and recommendations toward that end.

Integral to the matter of acceptance of an innovative method of this sort are the matters of effectiveness and time expenditure. In the early 1960's some investigators in programmed instruction used the measure, learning efficiency, defined as the ratio of learning criterion score (or gain score, pretest to posttest) to time consumed by learner in the lesson,46,47 and was used as a handy tool for comparing various program strategies. It has, however, been criticized methodologically on the grounds that the criterion score (or gain score) is formed from an ordinal scale and hence cannot be legitimately used in such a ratio.48


Lumsdalne proposes a method of assessment where first an agreed upon minimum criterion level be adopted, then the time expenditure required to reach such a level be the measure of assessment; this principle was conceived primarily with self-pacing instruction in mind, but it would seem readily adaptable to external pacing if the minimum criterion level were stated in group terms.

Thus the inverse of the instruction time needed in using a given programmed lesson to guarantee achievement of a minimum would become an important measure of program strategy evaluation.

The question of learning effectiveness and how it is to be defined from an evaluative standpoint is critical. Perhaps the most important study outcome that pertains to this matter is the diminishing strength of association going from response score criterion to delayed posttest. The delayed posttest assumes more importance when the practical question of applying the results of the study to an extended instructional sequence are considered. Learner retention over a delay interval is thus most apt to take highest priority in this instance.

One ready inference that might be drawn is that learner retention after five or seven days is not sensitive to the pace rate. Thus, if time economy were an important consideration, and if one were satisfied with the level of group achievement on the delayed posttest instrument as meeting a minimum level, it would follow that the faster pace would be the preferable one.

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Such a conclusion should be tempered with some caution for at least two reasons. (1) Additional evidence would be needed to establish attitudinal effects from external pace on student learners; for example, would a too-fast pace create an air of tension that would have the cumulative result over a series of lessons of alienating students? (2) Would there exist also a cumulative effect where the learning of content from lesson B presented on a Thursday, say, be dependent upon the successful retention of material from lesson A given on the preceding Tuesday? The interrelated matters of effectiveness and time expenditure cannot be completely settled so long as these questions are unanswered.

**Conclusion**

The study described in these pages was motivated by the prospect of combining programmed instruction in an externally paced context with the medium of video tape.

The result has been a research effort that attempted to answer certain questions regarding the lesson pace, learner aptitude and their interaction when using two disparate type of lesson content.

Some of these questions have been answered, some others only partially answered and new ones have been brought forth.
LESSON SCRIPTS

The following are the texts of the scripts which were read in making the audio-tape of the lessons. Numbers in parenthesis throughout the expository material indicate additional number of pause seconds that were inserted in the Expository Pause or Full Pause versions. Numbers in parenthesis following a question indicate the number of pause seconds left in for all versions; for the Question Pause and Full Pause versions, this number is doubled. Underlined words, phrases or formulas indicates material that appears in the visual context at the same time. When a sketch or figure accompanies a frame, this is so indicated by a phrase in parenthesis.

The point at which a new panel is placed on the screen is designated by "(new panel)." If while a frame question is being asked it happens that the panel on camera contains the answer to that question, then that portion of the panel is masked out.

Insect Lesson: Part One

The lesson that you are about to do is programmed for video tape presentation. You will be given an oral discussion accompanied by sketches and key words on the screen. The lesson is broken into two parts, each part to be followed immediately by a short test over the material just covered.

The lesson presentation is designed for you to actively participate as it goes along. At the end of periodic intervals a question will be asked and a short pause introduced so that you may write an answer on the sheet provided. At the end of the pause the desired answer will be given.

Don't be overly alarmed if you cannot answer all questions correctly. Do the best you can to concentrate on the material, however.
This particular lesson deals with the topic, insects. In this first part we will look at some of the predominant groups, or orders and their chief characteristics.

Insects belong to the Phylum known as Arthropoda. Insects with an outer skeleton or exoskeleton, and with jointed legs, belong to this phylum.

Other classes belonging to this phylum are spiders, crayfish, and centipeds.

Question 1: What is the phylum name to which the insect class belongs? The answer is Arthropoda.

The prefix arthro, in Greek means jointed, and poda, means foot, which freely translated, gives jointed leg.

Question 2: All animals belonging to the Arthropoda phylum besides having an exoskeleton, have what other common characteristic? Arthropods have jointed legs.

Questions 3 and 4: Besides insects, name at least two other animal classes that belong to the arthropods. For answers you could have written spider, crayfish, or centipeds.

Question 5: Besides having jointed legs, these animals have what other characteristic in common? They all have an exoskeleton.

We have looked at those things that insects have in common with other members of the arthropod phylum. Now let's see how they differ. Individuals in the class Insecta have three main body parts, separated by flexible joints in the exoskeleton. The spiders and crayfish, on the other hand, will have two main body parts. Insects also have three pairs of legs. Spiders by contrast have four pairs of legs, and crayfish five.

Question 6: The beetle, which is an insect, has how many main body parts? The answer is three.
Question 7. The housefly, which is an insect, has how many pairs of legs? (4)

The answer again is three. (6)

Question 8. How many main body parts do spiders and crayfish have? (4)

Spiders and crayfish have two main body parts. (6)

Insects are the only arthropods that have wings. (6) Some insects such as the primitive silverfish, have no wings. (6) Some such as the housefly, have one pair of wings; (6) many others, such as the butterfly and moth, have two wing pairs. (6)

Question 9. True or false: some species of spiders will have wings. (4)

The answer is false. (3) Only insect among the arthropods have wings. (6)

Question 10. True or false also. Some species of insects will have no wings. (4)

True. (3) The silverfish and ant are examples of insects without wings. (6)

Within the insect class are a number of orders each with their own characteristics. At least 29 insect orders have been identified. Here we will discuss six that are most commonly known. (6)

One of the most primitive orders is Thysanura, (6) meaning tasseltail in Greek. (6) The name is suggestive of the bristletail, found on members of this order. Pictured here is the silverfish which is a member of this order. (6)

The answer is Thysanura. (6)

Question 11. The silverfish with its tassel-like bristletail is a member of what order? (6)

The answer is Thysanura. (6)

Question 12. The word Thysanura, is derived from Greek where it means what? (5)

The answer is tasseltail. (6)
The order Orthoptera includes cockroaches, mantids, crickets as well as the one pictured here.

Question 13. What name would you give the one you see on the screen?

You see a grasshopper.

The name of the order Orthoptera, broken down into two parts, Ortho and Ptera suggests a certain type of wing structure. The names of insect orders are often, but not always, suggestive of the type of wings that its adult members might have. The suffix ptera, in the Greek means wing. The prefix ortho in Greek means straight.

Question 14. The word Orthoptera suggests what two word phrase describing a structure of this particular order?

The answer is straight wing.

Questions 15 and 16. Besides the grasshopper, name two other insects that belong to the Orthoptera order.

Possible answers are cockroaches, mantids, or crickets.

The order Hymenoptera includes wasps, ants, as well as the one pictured here.

Question 17. What name would you give this common insect?

You are looking at a bee.

The prefix, hymen, in the Greek means membrane.

Question 18. The order name, Hymenoptera suggests what two word phrase?

Hymenoptera suggests membranous wing. If one relied exclusively on the order name to identify members of an order it could be misleading. For instance, there are many different orders where membranous wings are evident besides in the Hymenoptera. Also within the Hymenoptera order are well known species that have no wings at all. These latter, as an example, are pictured here.

Question 19. What insect do you see on the screen?

The ant is pictured here.
Many of the insects in the order Hymenoptera, are known as social animals. These animals live and work closely together, cooperating in the activities of the hive, nest or colony, such as food gathering, feeding of the young and the defense of the group.

Question 20. Insects that work cooperatively together such as bees in a hive are known as what type of animals? The answer is social animals.

Question 21. Social insects are likely to belong to which order? The answer is Hymenoptera.

Questions 22 and 23. Name at least two members of the order Hymenoptera. Possible answers are wasp, bee, and ant.

The order Diptera includes the two winged insects such as flies and mosquitoes. Question 24. If the prefix, Di., means two, then the name Diptera suggests what? The answer is two winged insects.

Insects in the order Diptera are among the most troublesome to humans in terms of spread of disease.

Questions 25 and 26. Name two well known insects in the order Diptera. Examples given above were flies and mosquitoes.

The order Lepidoptera includes moths and butterflies. These insects have the colorful scales on their wings. Question 27. What meaning might you infer in the Greek prefix, Lepid? Lepid means scales in Greek.

Question 28. The name Lepidoptera, suggests what physical characteristic for insects in this order? Lepidoptera would mean scale wing.
Questions 29 and 30. Name two well known insects in the order Lepidoptera. (7)

(new panel: sketch of moth and butterfly) The moth, (3) and butterfly, (3) are the examples already mentioned. (6)

(new panel: sketch of beetle) The order having the greatest variety of species is Coleoptera, (6) or the beetles. (6) (new panel) The Greek word for sheath, (3) is Koleos. (6)

Question 31. Coleoptera must mean what type of wing? (5)

The answer is sheathed wing. (6)

(new panel: sketch of beetle with wings extended) The front wings, on a beetle are hard and sheath-like. (6) The hindwings are membrane-like and fold under when not in flight. (6)

Question 32. The order name to which beetles belong is what? (6)

(new panel) The answer is Coleoptera. (6)

(new panel: word Insects appears) We've introduced these six orders and learned how the name of each may suggest something about the wing or body structure. Let's review them.

(new panel: sketch of moth and butterfly) Moths and butterflies are noted for their colorful wings.

Question 33. What is it on their wings that is responsible for this color? (4)

The answer is scales. (6)

Question 34. What is the order name to which moths and butterflies belong? (6)

The answer is Lepidoptera, (3) meaning scaly wings in Greek. (6)

(new panel: sketch of silverfish) The primitive silverfish has no wings, but is noted for having a particular type of tail appendage. (6)

Question 35. What adjective would describe the silverfish's tail? (6)

The silverfish's tail is bristle-like, (3) or tassel-like. (6)

Question 36. What is the order name to which the silverfish belongs? (6)

The answer is Thysanura. (6)
The beetles make up the largest number of insects. The front wings of the beetle have a characteristic that suggests the order name.

Question 37. What characteristic describes the beetles front wings? (5)

Beetle forewings are sheathlike. (6)

Question 38. What scientific name is given to the beetle order? (6)

The answer is Coleoptera, meaning sheath-like wing. (6)

The beetle hindwings fold under the front wings when not in flight. Also these wings are not at all hard and sheath-like as are the front wings.

Question 39. Knowing this, what characteristic might describe the beetle's hindwings? (7)

Beetle hindwings are membrane-like. (6)

The social insects include the wasp, bee and ant. (6)

Question 40. The wings of the wasp and bee have what characteristic, suggesting the order name? (7)

All wing, front and hind, on the wasp and bee are membrane-like. (6)

Question 41. What is the order name to which wasps, bees and ants belong? (6)

The answer is Hymenoptera. (6)

The flies and mosquitoes also have mem braned wings. However, there is an important difference in wing characteristics compared to Hymenoptera. (6)

Question 42. What is that wing characteristic of flies and mosquitoes suggesting the order name? (5)

Flies and mosquitoes belong to the order Diptera. (6)

Grasshoppers, crickets, cockroaches, mantids belong to the order where the wings have a special shape. (6)

Question 44. What shape characteristic describes the wings of the insects? (6)

The grasshopper and its close relatives have straight wings. (6) Contrast this to the more rounded appearance of the beetle wing or bee wing. (3)
Question 45. What is the order name to which grasshoppers, mantids and crickets belong? (6)

The answer is Orthoptera, (3) meaning straight wing. (6)

(new panel) This concludes Part I for the lesson on Insects. You will have placed in your hands a set of questions that test your recollection of the things just covered in this lesson.

Insect Lesson: Part II

(new panel) We will continue with Part II on the Insect lesson. Follow the same procedure as before by filling in the answer sheets as the questions are asked. At the lesson's end another follow-up test will be given.

In this part we'll first look at the names of the main body parts, then examine two body processes in the insect; breathing and blood circulation; (3) and we'll finally consider the different life cycles that insects may have. (6)

(new panel: sketch of bee) Let's look at the names of the insect body parts and consider some of the characteristics of each. We'll use the bee sketch for illustration. (6) The three body parts of the insect, are named head, thorax, and abdomen. (6)

(mask words) Question 1. The body part in the middle is called what? (4)

The answer is thorax. (6)

Question 2. The body part of the insect that is at the posterior end is called what? (5)

The abdomen is located at the posterior end. (6)

Question 3. According to the diagram, the three leg pairs are all attached to what body part? (4)

All three leg pairs, as well as wings, are attached to the thorax. (6)

Question 4. According to the diagram, the eyes, antenna, and mouth parts of the insect are on which body part? (3)

These organs are attached to the head. (6)

Question 5. What is the name of the body part to which the wings are attached? (4)
The wings are attached to the **thorax**, as are the legs. (6)

(new panel: sketch of grasshopper showing spirical holes) Air is taken in and expired through a series of holes alongside the thorax and abdomen. These holes are called **spiricals**. (6) These spiricals lead to the inner organs and muscle fibers through tubes called **tracheae**. (6)

(mask words) Question 6. What name is given to the holes through which air enters and leaves the insect's body? (5)

The answer is **spiricals**. (6)

Question 7. The tubes leading from the spiricals are called what? (5)

These tubes are called **tracheae**. (6)

(new panel) The expansion and contraction of the **abdomen wall** is responsible for the air moving in and out.

Question 8. The abdominal expansion tends to reduce the pressure inside the body cavity, thus causing which to happen: air is taken in? or air is expelled (out)? (3)

Air is taken in when the abdomen expands. (6) The opposite is true when it contracts. (6)

(mask words) Question 9. Which of the three main body parts of the insect is most instrumental in the breathing process? (5)

The answer is **abdomen**, (5) which in expanding and contracting creates the flow of air. (6)

(new panel: sketch of circulatory system of grasshopper) The blood circulatory system is relatively simple in the insect compared to that found in the higher animals.

It consists of two main parts: a long tubelike heart, (3) located along the back, (3) and a body cavity, (3) called the **hemocoel**. (6) The system is filled with the colorless blood which surrounds the inner organs. (6)

(mask words) Question 10. Which organ in the insect's body does the actual pumping of blood? (4)

The heart does this pumping as in higher animals. (3) As it contracts, blood is forced out through the aorta towards the anterior end of the body. In the head region, the **aorta** opens into the body cavity. (6)

Question 11. What name is given to this body cavity? (5)
The body cavity is called the **hemocoele**. In it the body organs are surrounded by the clear **blood plasma** which transports food and wastes. To maintain the flow, blood will re-enter the heart at the posterior end when it is not contracted.

Question 12. What is the name of the tube which is anterior to the contracting heart and from which the blood flows into the hemocoele? (4)

The answer is **aorta**. (6)

Question 13. At which end of the insect's body does the blood enter the heart, the anterior or posterior? (5)

Blood re-enters the heart at the posterior end. (6) However, there are a few species of insects in which the flow direction is opposite to that described here.

Insects experience the senses of taste, smell, touch, sight, and hearing, as do the higher animals. However, the location of the sense organs are located in seemingly odd places.

Insects, such as the grasshopper, have two **compound eyes**, and between them a single **simple eye**. (6)

Question 14. On which of the three main body parts will the eyes be found? (4)

The correct answer, and probably obvious to you, is the **head**. (6)

The insect tastes with the mouth parts but some have been found to also have taste organs on the feet. (6)

Hearing organs may be found on various parts of the insect's body. Grasshoppers, for example, have these organs located on the front part of the abdomen just behind the large hind legs. (6)

Question 15. Which of the sense organs is found in the mouth parts and sometimes on the feet? (4)

The answer is **taste**. (6) The housefly is a good example of one that tastes with the feet as well as the mouth. (6)

The **hearing organ** is located here. (6)

Question 16. On the grasshopper, which sense organ is located on the abdomen just behind the hind leg? (4)

Questions 17 and 18. What two senses are located in the insect's **antennae**? (6)
Both **touch** and **smell** are made possible by the antennae. (6)

(new panel: sketch of female grasshopper laying eggs) We will look now at the various stages in the life of an insect. The sequence of stages depends upon the order to which the insect belongs. This sequence is called the life cycle. (6) Adult female insects will develop and lay eggs, (6) (new panel: sketch of newly hatched insect leaving egg case) from which emerges an individual of a new generation. (6) The individual will develop into an adult eventually. (6)

(new panel) Question 19. The sequence of stages in an insect's existence is termed what? (5)

The answer is termed **life cycle**. (6)

(new panel) The type of development which occurs in the life cycle from the point of emergence from egg to adult stage will differ considerably among the orders. Some types change very little in body structure, except for size, while others change very dramatically. The process of dramatic body structure change is known as **metamorphosis**. (10) There are three types of life cycles which we will describe. First, **no metamorphosis**. (6) Secondly, **gradual metamorphosis**. (6) And third, **complete metamorphosis**. (6)

(new panel: sketch of silverfish in different stages) Individuals in the order *Thysanura*, do not change in structure from time of emerging from the egg until up to the adult stage. (6) They only increase in size. (6)

Question 20. The silverfish, pictured here, experiences what type of **life cycle**. (8)

The silverfish, belonging to the order *Thysanura*, undergoes **no metamorphosis**. (6)

(new panel: sketch of grasshopper in different stages) Insects in the order *Orthoptera*, emerge from the egg with a similar but not identical appearance to the adult. The young grasshopper is called a **nymph**, (6) has no wings, (6) and has a proportionately larger head compared to the rest of its body. (10) Orthopterans are said to undergo **gradual metamorphosis**. (6)

(mask words) Question 21. What is the name of the grasshopper stage after it emerges from the egg? (4)

The very young grasshopper emerging from the egg is called the **nymph**. (6)

(new panel) The exoskeleton on an insect does not grow with the rest of the body. To accommodate the increasing size as the insect matures, it must shed the exoskeleton in a process called **molting**. (6)
Question 22. Molting is the process that accompanies the insect's changing in what characteristic? (4)

Size changes, necessitate molting. (6)

(new panel: sketch of grasshopper in different stages) After molting, the insect's body secretes a fluid which hardens to form a new exoskeleton. The new exoskeleton will eventually give way to yet another as the insect grows still larger, until finally it is a fully grown adult. During the successive molting periods the grasshopper will increase its body size proportionate to the head. (6) It will also change slightly in other respects. A glance at the sketch comparing adult to nymph makes this apparent. (6)

Question 23. As an adult what structures has it sprouted which it does not have as a nymph? (4)

As an adult it has wings. (6)

Question 24. What happens to the relative size of body to head during development from nymph to adult? (8)

The body grows larger as the grasshopper matures to adulthood. (6)

In the life cycle of the grasshopper as well as other members of the order Orthoptera, the structural changes are gradual from the time that it emerges from the egg until becoming an adult.

Question 25. The life cycle of an Orthopteran may be said to be of what type? (8)

Orthopterans, undergo gradual metamorphosis. (6)

(new panel: sketch of four life stages of beetle) Insects which have four distinct life stages are said to undergo complete metamorphosis. (6) By far the majority of insect species are of the type. This includes: the flies and mosquitoes; the ants, wasps and bees; the moths and butterflies; and the beetles. Here the change in structure from the newly hatched individual coming out of the egg to the final stage is very great. (6)

Question 26. This final stage is called what? (4)

The answer is, the adult stage. (6)

In complete metamorphosis, coming between the egg, and adult stage, are the larval, and the pupal. (6)

(mask words) Question 27. Which stage is wormlike in appearance? (4)

The larval stage is wormlike. (6)
In the larval stage much eating occurs. This particular stage is of particular consternation to crop growers who find their plants and fruits eaten by the larva.

Question 28. From the above you might infer that in the larval stage there is a considerable increase in what body characteristic? (4)

The larva increases in body size. (6)
The larva has an exoskeleton, just as the adult would have. (6)

Question 29. To accommodate the larva's growth size there must be a succession of what type of processes during this stage? (5)

The larva must molt to accommodate its increase in size. (6)

Question 30. A housefly maggot, or a butterfly caterpillar, are both wormlike and will represent what stage in the life cycle of these insects? (5)

These forms are the larval stage. (6)

Question 31. During the pupal stage the insect changes little in what body characteristic? (4)

There is little change in body size in the pupal stage. The pupa does not move while in this stage and hence is said to be quiet, or quiescent. (6)

It is during the pupal stage that the body structure changes dramatically. Here the legs, wings, and mature reproductive organs of the adult insect are forming. (6)

The moth cocoon, and the butterfly chrysalis, both represent the period of transition from caterpillar to adult. (6)

Question 32. In other words, they represent what stage for these insects? (4)

The cocoon, and chrysalis, are the pupal stage. (6) As was said above, the pupal is the quiescent stage. (6)

Question 33. The pupa, however, changes very dramatically in what characteristic? (5)

The pupa changes in body structure. (6)
Question 34. When an insect species is of the type that its life cycle goes from egg, to larva, to pupa, and finally to adult, then it is said to undergo what type of life cycle? (8).

The answer is complete metamorphosis. (6)

Now let's review some things about insect life cycles.

Question 35. Name an insect order where no metamorphosis occurs. (6)

Thysanura, of which the silverfish is an example, undergoes no metamorphosis. (6)

Question 36. Name an insect order where gradual metamorphosis occurs. (6)

Orthopterans, undergo gradual metamorphosis. (6)

Question 37. Name an insect order where complete metamorphosis occurs. (6)

Lepidoptera, Hymenoptera, Diptera, and Coleoptera, are orders where complete metamorphosis occurs. (6)

Question 38. In complete metamorphosis, which stage is the quiescent stage when no growth or movement occurs? (4)

This is the pupal stage. (6)

Question 39. In which stage does sexual union of male and female occur? (4)

This is the adult stage when sexual organs are mature. (6)

Question 40. Which is the stage in which much eating occurs? (4)

The wormlike larva, is a heavy eater. (6)

Question 41. In which stage is the insect the most active and mobile in complete metamorphosis? (4)

The adult, moves around more than any other stage. (6)

Question 42. In complete metamorphosis, which stage precedes the larval? (4)

The egg, precedes the larval. (6)
Question 43. In complete metamorphosis, which stage follows the larval? (4)

The pupal follows the larval. (6)

(new panel: sketch of grasshopper nymph emerging from egg)

Question 44. What name is given to a member of the order Orthoptera when it just emerges from the egg? (4)

Orthopterans undergo gradual metamorphosis, where it is the nymph that emerges from the egg. (6)

(new panel: sketch of bee) This concludes the lesson insects. You will have placed in your hands a set of questions that will test your recollection of the things presented in this lesson.

The script to follow is that used for the Simple Machines lesson. The same method of indicating the use of visuals will be followed as was done with the Insect script, i.e., either the key words shown will be underlined in the script or a description is given in parentheses. In the following lesson, a sizeable portion of the material will involve quantitative formulas and numerical solutions; in order to save space in the visual panel, much of this was written in symbol form. E.g., the symbol WD was used to represent work done.

In many cases the information in the visual panel is essentially identical to that read onto the audio tape, but in symbol form. When such is the case throughout the script it will be so indicated by the descriptive phrase in parenthesis such as "(new panel: pertinent formulas in symbol form)" or "(new panel: pertinent formulas and numerical solution)."
Simple Machines Lesson: Part I

(on panel: "Programmed Video Taped Lesson") The lesson that you are about to do is programmed for video tape presentation. You will be given an oral discussion accompanied by sketches and key formulas and words on the screen. The lesson is broken into two parts, each part to be followed immediately by a short test over the material just covered.

The lesson presentation is designed for you to actively participate as it goes along. At the end of periodic intervals a question or problem will be posed and a pause introduced so that you may work out and write an answer on the sheet provided. At the end of the pause period, the desired solution and answer will be given.

Don't be overly alarmed if you cannot answer all questions correctly. Do the best you can to concentrate on the material, however.

(new panel) This particular lesson deals with the topic, Energy and Force Relations in a Simple Machine. Here we will explore some general principles that apply to machines, such as mechanical advantage, (6) and efficiency, (6) and then consider the Inclined plane as a specific case.

(new panel) A simple machine may be thought of as a device that serves two main functions: 1. It may be used to transfer energy from one body to another, (6) and 2. It may be used to multiply forces. (6)

(new panel: sketch of person pushing on a lever to move object) As an example, a person in the sketch shown applies 50 pounds at one end of a simple machine lever, (6) to lift a 300 pound boulder. (6)

(new panel) Question 1. When described in this context, the lever as a machine serves which of the above two functions, energy transfer? (6) or force multiplication? (8)

The description of the lever as a simple machine given above makes its use to multiply forces. (6)

(new panel: person moving boulder with lever) The person in the above situation also does work in applying the force. (6) The boulder, in the process, gains potential energy. (6)

(new panel) Question 2. Here in this description the machine is seen as serving what function? (6)
The machine transfer energy. (6) Energy, as work done is transferred to the boulder. (6) (new panel: sketch of person moving boulder with lever) It is evident that a machine can perform both functions simultaneously. That is, it multiplies force and transfers energy at the same time. (6)

(new panel) The effectiveness of a simple machine may be characterized in either of two ways, by efficiency, (6) or mechanical advantage. (6)

(new panel: pertinent formula written out) Efficiency is the fraction of useful energy put out by the machine to that originally put into the machine as work done. (6)

(new panel) Question 3. When one considers machine efficiency, which of the two functions is most important, 1. energy transfer, (6) or 2. force multiplication? (6)

Energy transfer, (3) in a machine is most pertinent in describing its efficiency. (6)

(new panel: sketch of person moving boulder with lever) In the example given before with the lever, the boulder receives 200 foot-pounds of potential energy in being lifted, (6) while the person pushing the other end of the lever does 250 foot-pounds of work. (6)

Question 4. What is the lever efficiency? (8)

(new panel: pertinent formula and numerical work written out) Here the potential energy gained is the same as useful energy out of the machine. (6) The formula that we are using is: Efficiency equals the fraction of potential energy gain, (6) to work done, (6) which becomes two hundred, divided by two hundred fifty, (6) which equals 8/10ths. (6)

(new panel: sketch of person pulling object up incline) Let's apply the same formula to an inclined plane. (6) Here assume that the block pulled up the entire plane length will gain 450 foot-pounds, (3) and that 600 foot-pounds of work are done by the person pulling the rope. (6)

Question 5. What is the efficiency of this inclined plane as an energy transfer device? (8)

(new panel: pertinent formula and numerical work) The answer is 75/100ths. (6) Here, as with the lever, we take the ratio of potential energy gained by the block, (3) to work done by the person. (10)
In all real cases of energy transfer in a simple machine, the efficiency can never exceed one. (6)

Question 6. This means that in the case of the inclined plane or lever illustrations, potential energy gained can never be larger than what? (6)

Potential energy gained can never exceed original work done. (6) This is another way of saying that resultant energy out of the machine cannot exceed energy put into the machine. (10)

In any real simple machine process where the force of friction invariably is present, the work done as energy into the machine will, of necessity, be larger than any resultant energy out. (10)

In the process of overcoming this frictional force, heat energy is generated. (6) This is comparable to the heat energy you feel when you rub your hands together to keep them warm. (6)

The heat energy from frictional forces makes the difference. (6) This heat is regarded as dissipated or lost energy, in that it cannot be recovered for reuse in the machine. (10)

Returning to the example with the lever lifting the boulder, if 250 foot-pounds of work go into moving the lever and the boulder gains 200 foot-pounds in the process, then what dissipated energy as heat is produced? (6)

The answer is 50 foot-pounds, or the difference between work done and potential energy gained. (6) Here the potential energy gained by the boulder is the useful energy out of the machine. (10)

Useful energy out of a machine could be attributed to acceleration of the object receiving the energy, in which case its form is kinetic energy. (10) The useful energy could be that gained in lifting an object to some higher point above the ground or floor level. (6) This is potential energy gained, and was the case in both examples where the lever was used to lift the boulder, and the inclined plane was used to raise the block. (6)

For the rest of this lesson we will deal exclusively with cases where useful energy out of the machine is strictly potential energy gained by some object. (6)
Question 9. What may we assume happens physically to an object when it gains potential energy from a simple machine of the type described? (10)

It is lifted or raised to some higher point above the ground or floor than it was before the energy transfer occurred. (10)

(new panel) To simplify our writing we'll adopt some symbols to stand for certain quantities. (6) Let PE stand for potential energy gained. (10) Let WD stand for the work done which represents the energy put into a machine. (10) Let EFF stand for efficiency. (10)

Question 10. Write the formula using these shorthand symbols which expresses the efficiency value for a simple machine in terms of potential energy gained and work done. (10)

(new panel: pertinent formula written in symbol form) EFF is equal to PE divided by WD (10) Let's take a numerical example. (6)

(new panel: pertinent formula in symbol form with numerical work) Question 11. If in a simple machine the work done equals 50 foot-pounds and potential energy gained equals 35 foot-pounds, then what is the efficiency? (10)

Here efficiency equals PE divided by WD or 35 by 50, which is seven-tenths. (10)

(new panel: pertinent quantities in symbol form) If you know the machine efficiency and work done, it is possible to find the potential energy gained. (6)

Question 12. Write a formula expressing PE in terms of EFF and WD. (10)

Since EFF equals PE divided by WD (3) then it follows that PE equals EFF times WD. (10)

(new panel: pertinent formula and numerical work) Let's take a numerical example. (6) Question 13. If work done in lifting a simple machine is 200 foot-pounds, and efficiency is eight-tenths, (3) then what is the potential energy gained? (8)

PE equals EFF times WD or \( \frac{8}{10} \) times 200, (6) which is 160 foot-pounds. (10)

(new panel: formula pertinent to statement) We have emphasized that with the simple lifting machine the potential energy gained cannot exceed work done. (6) Also when frictional forces are present as they inevitably must be in a real process, at least some of that work done is dissipated as heat. (6)
We'll adopt another symbol, ED, to represent this energy dissipated. Remember the difference between the work done and useful energy out is the energy dissipated.

Question 14. Write an equation which expresses ED, as energy dissipated, in terms of PE and WD.

ED, or energy dissipated, equals WD, or work done, minus PE, potential energy gained.

Now let's use the same numerical example as before where work done was 200 foot-pounds, and potential energy gained is 160 foot-pounds. Question 15. What energy is dissipated?

Energy dissipated, ED, equals WD minus PE, or 200 minus 160, which is 40 foot-pounds.

It becomes a simple matter to rewrite the same equation so that work done is expressed in terms of energy dissipated and potential energy gained. Question 16. Express WD in terms of ED and PE.

By a simple algebraic operation WD, as work done, equals PE plus ED. Notice that so long as each of these three quantities are regarded as positive numbers then the requirement is satisfied that PE never exceeds WD.

A similar operation makes it possible to write potential energy gained in terms of work done and energy dissipated. Question 17. Express PE in terms of WD and ED.

PE, or potential energy gained, equals WD minus ED.

Notice again that work done is always the largest of these three quantities.

If potential energy gained in a simple lifting machine is 600 foot-pounds, and energy dissipated is 200 foot-pounds, then what is the work done?

Work done, WD, is PE plus ED, or 600 plus 200, which is 800 foot-pounds.

What is the efficiency of this same simple machine where potential energy is 600 foot-pounds, and energy dissipated is 200 foot-pounds?
Remember that EFF equals PE divided by WD which in this case is 600 by 800, (6) or 3/4ths, (3) or 75/100ths. (10)

(blank panel) Now let's try a slightly more complicated problem, (3) This will involve your keeping in mind two of the above relations, (6)

(new panel: numerical values given to pertinent quantities) Suppose a simple lifting machine has an efficiency of 6/10ths, (6) and work done is 500 foot-pounds. (6) Question 20. What is the energy dissipated? (15)

(new panel: numerical solution given) The answer is 200 foot-pounds. (6) You compute the potential energy as 6/10ths of 500, (3) or 300, (6) subtract this result from 500 (3) and arrive at 200 foot-pounds. (10)

(new panel: numerical values given to pertinent quantities) Suppose that in another simple lifting machine the energy dissipated is 400 foot-pounds (3) and potential energy gained is 400 foot-pounds. (6) Question 21. What is the machine efficiency? (15)

(new panel: numerical solution) The answer is 8/10ths. (6) To get this result we first find the work done, (6) which is the sum of PE and ED; (10) here, 400 plus 100, (3) or 500. (10) Efficiency then is the fraction of PE to WD, (6) or 400 by 500, (6) which is 8/10ths. (10)

(new panel) So far, we've looked at only one of the methods for characterizing a simple machine, namely the efficiency. (6) Let's look at the other characteristic, mechanical advantage. (6)

(new panel) There are two forms of the mechanical advantage. (6) One is the actual, (3) or AMA, (6) the other is the Ideal, (3) or IMA. (6) Let's define the actual mechanical advantage first. (6)

(new panel) In any simple lifting machine, the person doing the work must apply a force to make the machine operate. (6) We'll use the symbol, FA, (3) to represent that force applied. (6) The weight, of the object being lifted is instrumental also in the definition and will be represented by the symbol, WT. (10)

(new panel: pertinent formula in symbol form) Actual mechanical advantage equals object weight divided by force applied. (10)

(new panel) Question 22. Express AMA in terms of FA and WT using these symbols. (10)
The result is, \( \text{AMA} = \frac{WT}{FA} \).

The phrase, mechanical advantage, suggests that it is the factor by which the force applied is multiplied in order to lift a given weight. \( \text{AMA} = \frac{V}{T} \) equals the product of \( \text{AMA} \) time \( FA \).

Question 23. If the simple machine is to fulfill the purpose of multiplying the force applied then the actual mechanical advantage must be a number greater than what number?

AMA must be greater than one, if force is to be effectively multiplied in lifting the weight.

Let's take a numerical example. On an inclined plane which is a simple lifting machine, the force applied to the rope is 50 pounds in order to pull the 200 pound weight object up the plane.

Question 24. What is the actual mechanical advantage of this machine?

Actual mechanical advantage, \( \text{AMA} \), is \( \frac{WT}{FA} \) or 200 by 50 which is 4. Remember, actual mechanical advantage is the ratio of two force quantities, the weight of the object being lifted and the force applied.

Let's take a numerical example with a lever. Question 25. If an object weighing 400 pounds is lifted vertically on a lever due to a 50 pound force applied to the other end, what is the actual mechanical advantage?

The answer is 8 which is derived from the ratio of weight to force applied, or 400 by 50.

The ideal mechanical advantage of a simple lifting machine is defined in terms of the ratio of distance moved by the object being lifted, the vertical distance moved by the force applied.
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(new panel: pertinent numerical values given along with solution; sketch of lever shown) Question 26. If the object is lifted 1/10th foot, (3) while the force applied moves 1 foot, (3) what is the ideal mechanical advantage? (8)

The answer is 10. (6) The ratio of force-applied-distance, to vertical-distance of object, is 1 to 1/10th or 10. (10) Notice that the object weight and force applied have nothing to do in determining ideal mechanical advantage. *6) Only the distances moved are important. (10)

(new panel: "Programmed Video Tape Lesson") This concludes Part I of this lesson. You should have placed in your hands a set of questions and an answer sheet that covers this material. Do your scratch writing only on the space provided on the answer sheet.

Simple Machines Lesson: Part II

(blank panel) We're continuing with the second part of the lesson on simple lifting machines. Here we'll concentrate on the inclined plane.

(new panel: pertinent formula shown in symbol form) First let's review some of the important ideas from last time as applied to the inclined plane. Remember the three energy quantities. Work done, (6) equals potential energy gained, (6) plus energy dissipated. (6)

(new panel: pertinent formula in symbol form) Machine efficiency equals the ratio of potential energy gained to work done. (6)

(new panel: pertinent numerical values and solution given; sketch of inclined plane) Question 1. If work done equals 500 foot-pounds and machine efficiency is 7/10ths, (6) then what is the potential energy gained? (10)

The answer is 350 foot-pounds. (6) We know that efficiency is potential energy divided by work done. (6) Hence potential energy equals efficiency times work done. (6) Useful energy out, as potential energy gained, is 7/10ths times 500, (3) or 350 foot-pounds. (6)

Question 2. In this same case what is the energy dissipated? (10)

(new panel: numerical solution given) The answer is 150 foot-pounds which is the difference between work done and potential energy gained. (6)
In the case of the inclined plane as a simple lifting machine it is possible to express each of the energy quantities in terms of a product of force or weight, and length or height. Energy units that we're using are equivalent to the product of force units, times distance units. (10)

Question 3. If force or weight is measured in pounds and plane length or height is in feet, then the energy units are what? (6)

The answer is foot-pounds. (6)

On the inclined plane, work done, equals the product of force applied, times plane length. (10)

Potential energy gained, is the product, of object weight, times plane height. (10)

Energy dissipated is the product of force of friction times plane length. (10) Notice that FF is the symbol adopted to represent the force of friction. (6) Carefully remember these three relations.

Let's review with a numerical example.

An object weighing 400 pounds is pulled up a plane of length 20 feet and height 4 feet by a force of 100 pounds. (6) The force of friction is 20 pounds. (6) Question 4. What is the work done? (10)

The answer is 2000 foot-pounds. (6) Work done is the product of force applied and plane length or 100 times 20. (6)

Question 5. What is the potential energy gained by the object? (10)

The answer is 1600 foot-pounds, the product of weight times height or 400 times 4.

Question 6. What is the energy dissipated? (10)

The answer is 400, the product of force of friction times plane length. (6) This result is also consistent with the fact the energy dissipated, is the difference between work done, and potential energy gained. (10) Remember that any one of the three energy quantities will always be associated with either force or weight, and either plane length or height. (10)
Question 7. Energy dissipated is associated with plane length and what force? (6) 
The answer is friction, F. (FF)

Question 8. Work done is associated with force applied and what plane dimension? (6) 
The answer is plane length, L. (10)

Question 9. Potential energy gained is associated with object weight and what plane dimension? (6) 
The answer is plane height, H. (10)

Let's carefully review each of these relations once more: Work done equals force applied, times length of the plane. (10)

Potential energy gained equals weight of the object times height of the plane. (10)

Energy dissipated equals force of friction times length of the plane. (10)

Also work done, as energy into the machine, is the sum of potential energy gained, as useful energy out, plus energy dissipated. (10)

Now let's combine these relations in working a numerical example. Question 10. In a process on the inclined plane, a 300 pound object is pulled up a plane of length 20 feet and height 4 feet. (6) The force of friction is 15 pounds. (6) What work is done? (15)

The answer is 1500 foot-pounds. (6) We first use the data to determine separately the potential energy gained and the energy dissipated. (6) Potential energy gained is weight times height or 300 times 4 which is 1200 foot-pounds. (6) Energy dissipated is force of friction times length of the plane or 15 times 20 which is 300 foot-pounds. (6) These two products added together give 1500 foot-pounds. (6)

For practice, here's a similar problem. Question 11. A 200 pound object is pulled up a plane with length 15 feet and height 3 feet. (6) The force of friction is 20 pounds. (6) What work is done? (15)
Here potential energy gained is 200 times 3 or 600 foot-pounds and energy dissipated is 20 times 15 or 300 foot-pounds. The two added together gives the result of 900.

It is possible to express energy dissipated in terms of force applied, object weight, length of the plane and height of the plane. Question 12. In an inclined plane process, a force of 100 pounds is applied to an object weighing 400 pounds over a plane length of 15 feet. The plane height is 3 feet. What energy is dissipated in foot-pounds?

The answer is 300 foot-pounds. The first step is to find work done and potential energy gained separately. They are force applied, times length of plane, or 100 times 15, which is 1500 foot-pounds, and weight of the object, times height of the plane, which is 400 times 3, or 1200 foot-pounds. Energy dissipated is the difference of these two quantities, or 300 foot-pounds.

Potential energy gained may be determined from the difference between the calculated values of work done and energy dissipated.

Question 14. In an inclined plane process a force of 80 pounds pulls an object up an incline of 25 feet length. Force of friction is 20 pounds. What potential energy does the object gain in foot-pounds?

The answer is 1500 foot-pounds. Work done is 80 times 25, or 2000, energy dissipated is 20 times 25, or 500, and the difference is 1500 foot-pounds.

Question 15. What is the efficiency of this machine?

The answer is 75/100ths, found from the ratio of potential energy to work done, or 1500 to 2000, which is 75/100ths.
Now, let's evaluate the force quantities in terms of the energies and plane dimensions. Try this problem. Question 16. If a man does 900 foot-pounds of work pulling an object up an incline 20 feet long, (3) what force does the man apply? in pounds? (10)

The answer is 45 pounds; (6) since work done is the product of force applied, and plane length, (6) it follows that force applied is work done divided by plane length, (6) or in this case, 900 by 20, (6) which is 45 pounds. (6)

Question 17. If 300 foot-pounds are dissipated when the object is pulled up the plane of length 20 feet, (3) then what is the force of friction in pounds? (10)

The answer is 15 pounds. (6) The same type of reasoning is applied here as in the previous problem. Since energy dissipated is the product of force of friction and length of plane, (6) then force of friction is energy dissipated, divided by plane length, (6) or here, 300 by 20, (6) which is 15 pounds. (6)

Question 18. If an object gains 600 foot-pounds of potential energy while going up an incline of height 5 feet, (3) then what is its weight? in pounds? (10)

The answer is 120 pounds. (6) Weight equals the potential energy gained, divided by height of plane, (6) or 600 by 5, (6) which is 120 pounds. (6)

Question 19. If potential energy gained is 400 foot-pounds, (3) energy dissipated is 100 foot-pounds, (3) and plane length is 10 feet, (6) then what is the force applied? (15)

The first step in getting this result involves finding the work done. (6) This is the sum of potential energy gain, and energy dissipated, (6) or 400, plus 100, equals 500 foot-pounds. (6) Force applied is work done divided by length of the plane, or 500 by 10, (6) which equals 50 pounds. (6)

For practice, let's try another just like the one above. Question 20. What force is applied to an object on an inclined plane of length 15 feet, (3) when potential energy gained is 300 foot-pounds, (6) and energy dissipated is 150 foot-pounds. (15)
The answer is 30 pounds. Work done is 300 plus 150, or 450 foot-pounds, and force applied is 450 divided by 15, or 30 pounds.

Now, by a similar approach, one may find object weight, given work done, energy dissipated, and plane height. Remember, weight equals potential energy gain divided by height, and potential energy gain equals the difference of work done and energy dissipated.

Question 21. If work done is 1000 foot-pounds, energy dissipated is 200 foot-pounds, and height of the plane is 4 feet, what is the object weight?

The answer is 200 pounds. Potential energy is 1000 minus 200, or 800 foot-pounds. Weight is this 800 divided by 4, or 200 pounds.

Your experience with the above problems should make the following easy. Question 22. What is the force of friction on an inclined plane when work done is 1000 foot-pounds, potential energy gained is 700 foot-pounds, and length of the plane is 20 feet?

The answer is 15 pounds. First find energy dissipated which is the difference of work done and potential energy gained. This is 1000 minus 700, or 300 foot-pounds. Force of friction is this number divided by plane length or 300 by 20, which is 15 pounds.

Here's a slightly more complicated problem, but it requires only that you use the same relations that have already been discussed. Question 23. In an inclined plane process, what is the force applied by a man to pull up a 300 pound object, up a 20 foot length, and 4 foot height, when the force of friction is 30 pounds? in pounds?

The answer is 90 pounds. If you got this result, good. Relax for a moment while it is explained. Working backwards through the solution, you can see that force applied is work done, divided by length of plane. Work done is the sum of potential energy gained, or weight times height, and energy dissipated, or force of friction times length of plane. Okay. Potential energy is 300 times 4, or 1200 foot-pounds. Energy dissipated is 30 times 20, or 600 foot-pounds. These two added gives the result, 1800 foot-pounds for work done. Finally, 1800 divided by 20 is 90 pounds.
(new panel: numerical values given) Try another problem of the same form. Question 24. What is the force applied on an inclined plane when plane length is 10 feet, (3) plane height is 2 feet, (3) weight of the object is 400 pounds, (3) and force of friction is 20 pounds? (20)

(new panel: numerical solution given) The answer is 100 pounds. (6) Work done is the sum of potential energy, 400 times 2, (3) or 800 foot-pounds, (3) and energy dissipated, 20 times 10, (3) or 200 foot-pounds, (3) giving 1000 foot-pounds total. (6) This result divided by plane length is 1000 by 10, or 100 pounds. (6)

(new panel: pertinent quantities in symbol form; numerical values given) Now, when force applied, (3) weight of object, (3) length of the plane and height of the plane are known, (3) it should be possible to find force of friction, by the same procedure. (6) Question 25. What is the force of friction along an inclined plane when force applied is 60 pounds, (3) weight of the object is 300 pounds, (3) length of the plane is 20 feet, (3) and height is 3 feet? (20)

(new panel: numerical solution given) The answer is 15 pounds. (6) Energy dissipated is the difference between work done, and potential energy gained, or 60 times 20, (3) which is 1200 foot-pounds, (6) and 300 times 3, (3) which is 900 foot-pounds. (6) This difference of 300 when divided by 20 feet gives 15 pounds. (6)

(new panel: numerical values given) Question 26. What is the weight of the object pulled up an inclined plane when the force applied is 50 pounds, (3) force of friction is 30 pounds, (3) length of the plane is 10 feet and height is 2 feet? (20)

(new panel: numerical solution given) The answer is 100 pounds. (6) First find work done and energy dissipated. (3) These are, 50 times 10, (3) or 500 foot-pounds, (6) and 30 times 10, (3) or 300 foot-pounds. (6) The difference, as potential energy gained, is 200 foot-pounds, (3) and is divided by the height of 2 feet. (6) The result is 100 pounds. (6)

(blank panel) This concludes the video tape lesson. Now try the questions that have been passed out to you. Please remember to write only on the space allotted on the answer sheet.
APPENDIX B
CRITERION ITEMS: MATH PRETEST AND IMMEDIATE POSTTESTS

Math Skills Pretest

1. If you have the equation $15 = N + 3$, then $N =$?
2. If you have the equation $30 = N - 25$, then $N =$?
3. If you have the equation $N = a \times b$, $a = 5$, and $b = 20$, then $N =$?
4. If you have the equation $300 = 15 \times N$, then $N =$?
5. If you have the equation $N = (a \times b) + (c \times d)$, $a = 5$, $b = 3$, $c = 6$ and $d = 4$, then $N =$?
6. If you have the equation $4 \times N = 20$, then $N =$?
7. If you have the equation $6 \times N = (30 \times 5) - (7 \times 5)$, then $N =$?
8. If you have the equation $4 \times 15 = (5 \times N) - (7 \times 5)$, then $N =$?
9. If you have the equation $4 \times N = (3 \times 9) - 11$, then $N =$?
10. If you have the equation $50 \times N = (900 \times 3) + (400 \times 2)$, then $N =$?

Insect Immediate Posttest: Part One

1. What is the name of the phylum to which insects belong? (***)
2. What is the order name to which flies and mosquitoes belong? (*)
3. Name one example of a member of the order Orthoptera. (**)
4. How many wing pairs does the moth have? (**)
5. Which of the orders of insects studied most exemplifies social behavior?

(*) Indicates use of same item on pretest
(**) Indicates use of same item on delayed posttest
(***) Indicates use of same item on both pretest and delayed posttest
6. What is the scientific name for the order to which the beetles belong? (***)

7. What does the prefix, arthro, mean in Greek? (**)

8. What does the suffix, ptera, mean in Greek?

9. What does the prefix, ortho, mean in Greek? (***)

10. What does the prefix, Koles, mean in Greek?

11. What word or words does the order name, Lepidoptera, suggest from Greek? (***)

12. What word or words does the order name, Diptera, suggest from Greek? (**)

13. and 14. Name two other common classes that belong to the same phylum as insects. (**)

15. Name an insect in the order Thysanura. (*)

16. Name an insect in the order Lepidoptera. (**)

17. The grasshopper is a member of what order? (**)

18. How many leg pairs does the cricket have? (**)

19. How many wing pairs does the beetle have? (**)

20. How many main body parts does the insect have?

21. What word or words does the name Thysanura from Greek suggest? (**)

22. What word or words does the name, Hymenoptera, from Greek suggest? (**)

23. The front wings of a beetle have what characteristic? (in one or two words)

24. The front wings of a wasp have what characteristic? (in one or two words) (**)

25. The cockroach is a member of what order? (**)

26. The hindwings of a beetle have what characteristic? (In one or two words) (**)

27. The bee is a member of what order?
28. The suffix, *poda*, means what in Greek?

29. Name an example of an insect in the order *Diptera*. (***)

30. The hindwings of the wasp have what characteristic? (in one or two words) (***)

31. and 32. All animals belonging to the same phylum as the insects have what two characteristics in common? (in one or two words)

33. How many leg pairs does the housefly have?

34. Name another insect belonging to the same order as the ant. (***)

35. Name another insect belonging to the same order as the moth. (***)

36. Which insect order contains the greatest number of different types? (***)

37. The mantid, or praying mantis, belongs to what order?

38. Insects that work cooperatively together are known as what type of animals? (***)

39. Insects in what order studied are most troublesome to humans in terms of spread of disease? (***)

**Insect Immediate Posttest: Part II**

1. What name is given to the insect body part to which the legs are attached? (*

2. What are the openings in the insect's body called through which air enters and leaves? (***)

3. Which body part expands and contracts creating a flow of air? (***)

4. What is the name of the body cavity in which blood surrounds and bathes the organs? (***)

5. What sense organs are found on the insect mouth parts and sometimes the feet?

6. The complete sequence of stages in an insect's existence from one generation to the next is called what?
7. What name is given to the grasshopper just after emerging from the egg? (**)  

8. Shedding the exoskeleton in an insect is a process called what? (***)

9. Shedding the exoskeleton is a process that accompanies what other process of change in the insect?  

10. What type of life cycle characterizes the Thysanura? (***)

11. A grasshopper, by the time it is adult, has sprouted a fully developed set of what structures that it did not have as a newly hatched individual? (**)  

12. Which part of the very young grasshopper's body is proportionately larger compared to what it is when an adult? (**)  

13. What is the main body part to which the insect's wings are attached? (**)  

14. What name is given to the dramatic changes in body structure that many types of insects experience in the life cycle? (*)  

15. What name is given to the quiescent stage in the life cycle of the beetle? (***)  

16. On a grasshopper the hearing organs are located on which main body part? (***)  

17. and 18. What two senses are found on the insect's antennae? (*)  

19. The butterfly caterpillar represents what stage in its life cycle? (*)  

20. In which stage of the life cycle of a beetle does sexual union occur?  

21. In which stage of the life cycle of the beetle does much eating occur? (**)  

22. What type of life cycle does a member of the order Diptera experience? (**)  

23. Which stage follows the egg in the life cycle of the order Lepidoptera?  

24. Which stage precedes the adult in the life cycle of the order Hymenoptera? (**)
25. What type of life cycle does an individual in the Orthopteran order experience? (***)

26. In which stage (other than the egg) of a Hymenoptera life cycle does there occur much change in body structure but little growth? (*)

27. What is the name of the breathing tubes that lead to the inner organs and muscle fibers of the insect? (**) 

28. What is the name of the main body part at the posterior end (opposite the head) of the insect's body? (**) 

29. What is the name of the tube connected and located anterior to the heart, from which blood enters into the large body cavity? (**) 

30. What type of life cycle does an individual in the order Coleoptera experience? (**) 

31. On which main body part are insect's antennae attached? (***) 

32. The housefly maggot represents what stage in its life cycle? (*) 

33. The butterfly chrysalis represents what stage in its life cycle? (***) 

34. What type of life cycle does a praying mantis experience? (**) 

35. What name is given to the cockroach individual just after it emerges from the egg? (**) 

36. What type of life cycle describes that where the individual emerging from the egg most resembles the adult in appearance (except for size)? 

Five additional items, two of which also appeared on the pretest, were placed on the immediate posttest, but were excluded in the final analysis.
Simple Machines Immediate Posttest: Part I

1. If a boulder is lifted by a lever receiving 200 foot-pounds of potential energy in the process, while the person operating the lever does 250 foot-pounds of work, then what is the lever's machine efficiency? (*)

2. If the work done by a man pulling an object up an inclined plane is 700 foot-pounds and potential energy gained by the object is 200 foot-pounds, then what is the energy dissipated (in foot-pounds)? (*)

3. 2000 foot-pounds of work are done in pulling an object up an inclined plane with efficiency of .7. What potential energy is gained by the object in the process? (*)

4. When an object is pulled up an inclined plane, if energy dissipated is 350 foot-pounds, and the potential energy gained by the object is 400 foot-pounds, then what work is done (in foot-pounds)? (*)

5. When an object is pulled up an inclined plane, if the work done is 1600 foot-pounds and energy dissipated is 700 foot-pounds, then what is the potential energy gained by the object (in foot-pounds)? (*)

6. What is the efficiency of a simple machine where potential energy gain is 600 foot-pounds and energy dissipated is 200 foot-pounds? (express as a decimal)

7. If a simple lifting machine has an efficiency of .6 and work done is 500 foot-pounds, then what is the energy dissipated? (*)

8. If an object pulled up an inclined plane has a weight of 320 pounds, the force of friction along the plane is 20 pounds, force applied by the man is 80 pounds in pulling the object, plane length is 15 feet and plane height is 3 feet, then what is the actual mechanical advantage (AMA) of this inclined plane? (*)

9. For the same inclined plane described in question 8 above, what is the ideal mechanical advantage (IMA)?

10. 3000 foot-pounds of work are done in pulling an object up an inclined plane with an efficiency of .7. What energy is dissipated in the process (in foot-pounds). (*)

(*) Indicates use of same item on delayed posttest but with numerical values changed.
11. If an object is lifted by a lever and receives 450 foot-pounds of potential energy in the process, while the person operating the lever does 500 foot-pounds of work, then what is the lever's machine efficiency? (express as a decimal) (*)

12. What is the efficiency of a simple machine where potential energy gain is 800 foot-pounds and energy dissipated is 200 foot-pounds? (express as a decimal)

13. If the work done by a man pulling an object up an inclined plane is 1500 foot-pounds and potential energy gained by the object is 1100 foot-pounds, then what is the energy dissipated (in foot-pounds)?

14. If a simple lifting machine has an efficiency of .8 and work done is 300 foot-pounds, then what is the energy dissipated (in foot-pounds)? (*)

15. 3000 foot-pounds of work are done in pulling an object up an inclined plane with efficiency of .8. What potential energy is gained by the object in the process (in foot-pounds)? (*)

16. If an object pulled up an inclined plane has a weight of 600 pounds, the force of friction along the plane is 50 pounds, force applied by the man is 150 pounds in pulling the object, plane length is 300 feet and plane height is 5 feet, then what is the Ideal mechanical advantage (IMA) of the inclined plane?

17. For the same inclined plane process described in Question 16 above, what is the actual mechanical advantage (AMA)?

18. When an object is pulled up an inclined plane, if energy dissipated is 400 foot-pounds and the potential energy gained by the object is 600 foot-pounds, then what work is done (in foot-pounds)?

19. 2000 foot-pounds of work are done in pulling an object up an inclined plane with an efficiency of .6. What energy is dissipated in the process (in foot-pounds)?

20. When an object is pulled up an inclined plane, if the work done is 1400 foot-pounds and energy dissipated is 500 foot-pounds, then what is the potential energy gained by the object (in foot-pounds)?
Simple Machines Immediate Posttest: Part II

The following questions all deal with the process where a man is pulling an object up an inclined plane.

1. If an object pulled up an inclined plane has a weight of 300 pounds, the force of friction along the plane is 20 pounds, force applied by the man is 80 pounds in pulling the object, plane length is 15 feet and plane height is 3 feet, then what work is done by pulling the object (in foot-pounds)?

2. For the same inclined plane process described in Question 1 above, what is the potential energy gained by the object (in foot-pounds)?

3. For the same inclined plane process described in Question 1 above, what energy is dissipated (in foot-pounds)?

4. If the force of friction is 30 pounds, object weight is 200 pounds, plane height is 5 feet and plane length is 20 feet, then what work is done by the man applying the force in pulling the object up the incline (in foot-pounds)?

5. If 180 foot-pounds of energy are dissipated when an object is pulled 10 feet up an inclined plane, then what is the force of friction along the plane (in pounds)? (*)

6. If an object gains 600 foot-pounds of potential energy when lifted up an incline of length 20 feet and height 5 feet, then what is the object weight (in pounds)? (*)

7. If 500 foot-pounds of work are done by a person pulling an object up an inclined plane 20 feet long, what force parallel to the plane does that person apply in the process (in pounds)?

8. In an inclined plane process, if the work done is 800 foot-pounds, energy dissipated is 300 foot-pounds, plane length is 20 feet and plane height is 4 feet, what is the force of friction (in pounds)? (*)

9. From the same data in question 8 above, what is the weight of the object (in pounds)? (*)

10. If 30 pounds of force are applied to pull the object weighing 120 pounds up a plane with height 4 feet and length 20 feet, what is the force of friction (in pounds)? (*)
11. In an inclined plane process, if the force applied by the man is 100 pounds, the force of friction is 20 pounds, plane length is 30 feet and plane height is 6 feet, then what potential energy is gained by the object pulled up the plane (in foot-pounds)? (*)

12. From the data of Question 11, what is the weight of the object pulled up the plane (in pounds)? (*)

13. If the weight of the object pulled up the plane is 400 pounds, force of friction is 20 pounds, plane length is 15 feet and plane height is 3 feet, what is the force applied by the man pulling up the plane (in pounds)? (*)

14. If 600 foot-pounds of work are done by a person pulling an object up an inclined plane 30 feet long, what force parallel to the plane does that person apply in the process (in pounds)? (*)

15. If 40 pounds of force are applied to pull an object weighing 120 pounds up a plane of height of 3 feet and length 10 feet, what is the force of friction (in pounds)? (*)

16. If an object gains 400 foot-pounds of potential energy when lifted up an incline of length 15 feet and height 5 feet, then what is the object weight (in pounds)? (*)

17. If the weight of the object pulled up the incline is 1000 pounds, force of friction is 40 pounds, plane length is 25 feet and plane height is 4 feet, what is the force applied by the man (in pounds)? (*)

18. In an inclined plane process, if the work done is 1000 foot-pounds, energy dissipated is 200 foot-pounds, plane length is 20 feet and plane height is 4 feet, what is the force of friction (in pounds)? (*)

19. From the same data in Question 18 above, what is the weight of the object (in pounds)? (*)
IMMEDIATE POSTTEST ITEM ANALYSES

The following tables show the difficulty (by percentage missed) for each item used on the immediate posttests. Also shown is a cross reference to a given frame (by question number) in the corresponding lesson (see Appendix A) and also by major lesson topic (Chapter III, pages 27 and 31).

**Insects Immediate Posttest: Part One**

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Simple Machines Immediate Posttest: Part One

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The estimated strength of association, symbolized by $\omega^2$ (Greek omega squared), may be computed by either of two formulas, depending upon the nature of the original analysis.

(1) When $t$-test is used, the following formula is applied:

$$\text{estimated } \omega^2 = \frac{t^2 - 1}{t^2 + N - 1}$$

where: $t$ is the criterion ratio customarily used in a two group comparison and $N$ is the total number of cases in both groups.

(2) When an analysis of variance is used to find an $F$ ratio, the following formula is applied:

$$\text{estimated } \omega^2 = \frac{(\text{SS between}) - (\text{df} \times \text{MS within})}{\text{SS total} + \text{MS within}}$$

where: $\text{SS between}$ is sum of the squares between corresponding to main effect or interaction under consideration.

$\text{df}$ is degrees of freedom corresponding to main effect or interaction under consideration.

$\text{SS total}$ represents total sum of squares for all main effects, interactions and within groups.

$\text{MS within}$ represents mean sum of the squares within, found by dividing sum of the squares within by degrees of freedom within.

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50Hays, op. cit., p. 327.

51Hays, op. cit., p. 382.


