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AN EXPERIMENTAL EVALUATION OF METHODS FOR IMPROVING "CONVENTIONAL" TELEVISION LESSONS. STUDIES IN TELEVISED INSTRUCTION. FINAL REPORT.

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A NUMBER OF PROCEDURES FOR IMPROVING THE CONVENTIONAL TELEVISION LESSON WERE EVALUATED. THREE VERSIONS OF A TELEVISION LESSON ON LEVERS WERE COMPARED--(1) A VERSION OF AN EXISTING, CONVENTIONAL LESSON USED AS A CONTROL TREATMENT, (2) A VERSION INTENDED TO FACILITATE RETENTION OF SCIENCE CONCEPTS AND PRINCIPLES, AND (3) A VERSION INTENDED TO FACILITATE TRANSFER OF THE CONCEPTS AND PRINCIPLES LEARNED TO NEW CONTEXTS. REVISIONS IN THE LESSON INCORPORATED MANY FEATURES OF PROGRAMED INSTRUCTION. CHANGES MADE REVOLVED ABOUT THE STIMULUS FEATURES OF THE PRESENTATION ONLY. FROM THE RESULTS IT WAS CONCLUDED THAT CONCENTRATION ON THE STIMULUS ALONE, WHILE NEGLECTING THE RESPONSE, PRODUCED IMPROVEMENTS OVER THE CONVENTIONAL LESSON, BUT FELL SHORT OF AIDING THE STUDENT TO ACQUIRE, RETAIN, AND TRANSFER LARGE AMOUNTS OF INFORMATION. (AL)

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STUDIES IN TELEVISED INSTRUCTION: FINAL REPORT

AN EXPERIMENTAL EVALUATION OF METHODS FOR IMPROVING "CONVENTIONAL" TELEVISION LESSONS

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and
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October 1966

American Institutes for Research
Pittsburgh, Pennsylvania

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INTRODUCTION

Recent research on instructional television has demonstrated ways in which the level of instructional effectiveness can exceed that usually attained with "conventional" television lessons. The innovations which have led to greater effectiveness derive from the instructional technology represented in programmed instruction. Carpenter and Greenhill (1963) applying programming techniques to television have effectively prepared entire courses on English and math. In a series of separate studies using individual lessons, Gropper, Lumsdaine, et al. (1961a,b,c,d,e) have demonstrated experimentally the value of: pre-testing and revising television lessons, programming lessons, and requiring active responses. More recently Gropper (1965, 1966) has extended the programming approach effectively to the visual, demonstration portions of lessons as well as to the verbal portions.

In these various studies, lessons take on a format and character distinctively different from a conventional television lecture or television lesson. They are divided into well delineated segments. The segments are sequenced in systematic ways with each segment building on the just prior segment. Provisions are made for continuous "active student response" with confirmation provided immediately after each response.

Producers of the conventional television lesson adopt few of these features systematically as a matter of policy. Rather, the conventional television lesson can be characterized as providing the standard form of lecture presentation, often aided by demonstrations or other visual materials and, perhaps, on occasion using interpolated questions. In view of the growing evidence of the contributions to instructional effectiveness which programming features make, it appears appropriate to look to the behavioral principles and techniques that underlie programmed instruction and to determine whether the television lesson in conventional form can be improved through their implementation. It is, therefore, the intent of this study to investigate ways in which the conventional television lesson can be improved through the application of learning principles.

Controlling Student Behavior During Instruction

One of the principal goals of programmed instruction is to exercise precise control over the conditions under which learning occurs. The fragmentation of lessons into discrete segments serves this purpose. It facilitates student practice of specific responses in the presence of specific stimuli, thus minimizing the opportunity for the practice of adventitious responses or the practice of correct responses in the presence of inappropriate stimuli. It further provides immediate reinforcement following response practice, rather than at some later time. Adherence to these conditions, promotes efficiency in learning. Student responses readily and efficiently come under the control of the stimulus material contained in the lesson. Although stated in a relatively abstract way, this is the general aim of all instruction. Stated somewhat more concretely and specifically, two principal aims of instruction appear to be: (a) to facilitate the acquisition and retention of responses and (b) to facilitate transfer of these responses to new situations.

The preparation of conventional lessons, whether live in the classroom or on television, has rarely been preceeded by the kind of careful and systematic analysis of behavioral outcomes which characterizes the preparation of programmed lessons. It would appear that the conventional television lesson might be significantly improved by an analysis of the learner's task when he is expected to learn from a conventional lesson. Methods to facilitate his task could then be devised such that learning will more efficiently be a function of the instructional materials presented to him.

Analysis of the Task of Learning from a Conventional Television Lesson

The learning process can be better controlled as a function of conventional instructional materials presented on television through an analysis of the student's task in learning from them and through an analysis of the problems which may arise. In a general sense, all undesirable outcomes can be considered as being made up of three components: a failure to identify what it is to be learned; a failure to retain the information successfully identified; or a failure to apply the retained information properly in post-instructional situations.

(1) failure to identify what is to be learned

As a first step in learning from a conventional television lesson, the student must be able to identify just what it is he is to learn. Often what the student regards as important will not correspond closely with the intended objectives of the lesson. Or, an important point may be so buried in a welter or irrelevant or even relevant detail that the student fails to respond to it. A conventional lesson must therefore be prepared so that it aids the student to identify the important points.

(2) failure to retain what has been identified

Learning may still encounter failure if information in a lesson which has been successfully identified as being important is nevertheless not retained. Failure to retain information can be diagnostic of inadequate conditions of practice or review or perhaps even initially of an inability to attract the student's attention. The preparation of conventional lessons must also deal with this second source of possible failure.

(3) failure to apply retained information

Even if information is adequately retained, a further failure is possible. Particularly when concepts and principles are being learned, they may be inadequately presented so that the learner may fail to apply them to new, appropriate situations, situations other than the specific ones encountered in a lesson. Steps must be taken to build into lessons procedures or materials which facilitate this kind of appropriate transfer.

Approach

The purpose of the present study is to evaluate a number of procedures for improving the conventional television lesson. The procedures are based on a number of hypotheses concerning techniques for avoiding the kinds of potential learning failures described above:

1. Successful identification of points to be learned is a function of the clarity, specificity, and difficulty level with which they are presented. Accordingly,

successful identification by the student of the points to be learned can be aided by:

   a. isolating or designating the main points to be learned
   b. isolating or designating supporting materials
   c. omitting extraneous or unnecessary points
   d. adjusting the difficulty level of examples, vocabulary, grammar, or sentence length.

2. Successful retention of material is a function of conditions of review, the concreteness of examples, and the interest level of examples. Accordingly, successful retention can be aided by:
   a. increasing the amount, variety, and relevance of review
   b. improving the spacing of review
   c. increasing the interest level of examples
   d. using visual examples.
3. Successful application or transfer of what has been learned is a function of the breadth of the context in which it is learned initially; i.e., the kinds and number of examples used. Accordingly, successful application can be aided by:
   a. increasing the number and variety of examples
   b. omitting irrelevant examples
   c. including positive <u>and</u> negative examples (e.g., of the applicability of a term)
   d. using appropriate connective passages linking principles and examples
   e. increasing the likelihood that the student will anticipate the outcome of examples.

While many of these features of programmed instruction can be applied to a conventional lesson, one feature cannot without changing its conventional "look."

that is repeated active responding followed by confirmation throughout the entire length of a lesson. While provision can be made (and in this study was made) for anticipatory responses (by interpolating pauses), no systematic efforts can be made for this purpose and still have the lesson appear "conventional." No measures (such as use of workbooks, for example) can be taken to insure that students will actually make responses. None were taken in the present study. The intent of the present study, therefore, was to determine, primarily whether application of programming techniques only to the stimulus features of a conventional presentation (their design, sequencing, etc.) can measurably increase its effectiveness.

It is not the intent of the present study to concern itself with an experimental comparison directed to each of the possibilities hypothesized above. Rather, it is intended to incorporate several techniques within an experimental lesson as an attempt to maximize differences between treatments. Three treatments are envisaged, one of which is a control treatment. Of the other two, one is intended to facilitate retention of science concepts and principles. The other is intended to facilitate the transfer of concepts and principles learned to new contexts. Both treatments represent modifications of an original lesson, which serves as a control. This study thus involves the revision of an existing lesson in order to achieve specific predictable behavioral outcomes.

Tryout and revision are integral steps in the preparation of programmed materials. Programs are revised until they meet some predesignated standard. This goal has also been sought in non-programmed instruction. Gropper, Lumsdaine, and Shipman (1961a) demonstrated the value of applying the tryout and revision process to conventional television lessons. The need for empirical tryout and subsequent revision is, it would seem, well understood today. But a frankly empirical approach to the preparation of instructional materials cannot be equated with the development of an instructional technology. A highly developed instructional technology may always require empirical tryout. But, by definition, it should require only minimal revision. To reach this stage of sophistication requires a tested body of principles, techniques, procedures for the initial preparation of lesson materials. Only as the need for revision approaches (zero) can we truly say that we possess a technology of instruction.

Greater sophistication in the tryout phase itself can lead first of all to the need for fewer and fewer revisions. It can, more importantly, lead to the formulation, evaluation, and demonstration of principles, which, if applied in the initial preparation of lesson materials, can lead to the need for minimal revision. This study attempts such an approach. It seeks through the use of diagnostic tests to pinpoint particular types of learning task failures in existing lessons. It further seeks, by means of the various techniques suggested above, to correct those failures and to demonstrate their effectiveness in revised versions of the same lesson.

The general approach to be followed may be summarized as follows:

(1) development of tests diagnostic of particular types of learning failures in an existing lesson;

(2) administration of standard achievement and diagnostic tests following administration of an existing lesson (prepared for television);

(3) revision of the lesson to improve retention and to improve transfer by means of techniques described above; and

(4) comparing the original and two revised versions experimentally.

It should be made clear that this study is not designed to demonstrate the value of empirical tryout. This has been amply demonstrated in the past. This study is employing the tryout process merely as a means of developing principles that can minimize the need for revision following tryout. Thus, it is not the tryout process per se that is to be evaluated. What is to be evaluated are specific techniques for preparing television lessons presented in conventional form that will facilitate retention and transfer.

While this study is not primarily concerned with the tryout process per se, techniques to be employed in it are likely to be applicable to the routine tryout of instructional materials. These techniques concern the systematic attempt to diagnose particular types of learning failures -- in addition to attempts to identify specific items of lesson content inadequately learned. Items diagnostic of particular types of learning failures, in addition to identifying specific content inadequately learned, also suggest specific ways of improving lesson presentation.

METHOD

Materials

Three versions of a lesson on levers were compared experimentally. One was an existing lesson; the second was a revised version of the original lesson that was specifically designed to facilitate retention; and the third was also a revised version of the original, this time specifically designed to facilitate transfer. Revisions were based on results obtained from diagnostic and achievement tests administered to a sample of seventh-grade students comparable to the target population.

1. Lessons

The original lesson on levers had been prepared for an earlier project (Gropper & Lumsdaine, 1961). It was a conventional lesson that had undergone empirical tryout and revision, but, compared to standards typically set for programmed instruction, had still produced relatively low achievement levels. The possible criticism that bias may have entered in the selection of a particular substandard lesson may be answered as follows. It is not the intent of this study merely to show that tryout and revision can produce improvements. It is the intent to determine if specific types of improvement can be brought about through the application of specific behavioral principles. Thus, two experimental versions were produced, one designed for retention, the other for transfer. Selecting an existing lesson that failed to produce high levels of achievement, thus, could not be expected to have systematically influenced learning outcomes made possible by one version and not by the other. Moreover, empirical results based on tryouts indicated that the original lesson was equally inadequate for both retention and transfer purposes.

The script for the original television lesson on levers appears in its entirety in Appendix A. The concepts and principles covered in this lesson, which lasted approximately 28 minutes, included:

(1) force and motion;

(2) the relationship between the direction of a force and the direction of movement;

(3) the relationship between the weight of an object and magnitude of the force needed to lift it;

(4) a comparison of the magnitudes of the applied force and lifting force when a lever is used to lift objects;

(5) definitions of the terms: machine, levers, applied forces, and lifting forces;

(6) identification of the direction of the applied and lifting forces;

(7) the relationship between the position of the fulcrum and the magnitude of the applied force required;

(8) the relationship between lever arm ratios and the ratio of applied to lifting force;

(9) the definition of work;

(10) the relationship between work put in and work put out (when a lever is used); and

(11) the relationship between the distance through which an applied force is exerted and the distance through which the lifting force is exerted.

As can be noted from the length of the list, this was an ambitious goal for a 28-minute lesson. Since this version failed to do an adequate job of teaching all these concepts and principles, there were two possible ways to improve it: (1) keep the lesson the same length (duration) but reduce the number of concepts and principles to be taught; or (2) lengthen the lesson (duration) making it less efficient but also making it possible to be more effective. The second path was followed resulting in separate retention and transfer versions each lasting approximately 55 minutes. The scripts for both retention and transfer versions have large sections in common; the primary difference between them consisting of the use of more <u>varied</u> examples in the transfer version. The scripts for both versions also appear in Appendix A.

Even after revision the two experimental lessons remained <u>conventional</u> television lectures. No systematic attempt was made to require active responding. While many pauses were introduced in the lesson to encourage anticipatory responding (to solve problems), as is usually done in any good lecture, no work booklets were distributed for recording responses. Nor were special instructions or explanations given to encourage responding. Since no systematic provisions were made to encourage "on cue" responding, the behavioral principles applied in the revision of the original lesson thus had to do primarily with the design and preparation of the stimulus materials only.

Changes made in the revised version of the original script may be described as general and as specific in purpose. General changes were based on good instructional and good television production practice that might be expected to lead to heightened instructional effectiveness. Specific changes were based on specific inadequacies identified in the original lesson by means of diagnostic tests.

Behavioral principles underlying programmed instruction (save for the requirement of response practice) were implemented as a general way of improving the original lesson. For example, to facilitate discrimination practice on which concept acquisition is contingent, positive and negative examples were used, contrasting examples were used, etc. To facilitate generalization, multiple and varied examples were used. To facilitate retention (and transfer which is contingent on it) more review was introduced. Some of the television production techniques employed to make improvements over the original lesson included greater use of close-ups (and less use of the lecturer's face), ample use of supers (e.g., arrows to indicate the direction of forces, or lines to indicate the position a lever had been in after it was pushed down, etc.).

Specific changes introduced were based on identified weaknesses in the original lesson. The identification was made by means of specially designed diagnostic instruments.

2. Diagnostic tests

Diagnostic instruments were designed to accomplish two things: (1) to pinpoint student inability to identify what was supposed to be learned, to retain what was identified, and to transfer what was retained to new, but related situations; and (2) to obtain a measure of response strength.

(a) diagnosis of learning failures. - A student cannot transfer a concept or principle to a new situation if he has failed to retain the concept. He cannot retain it if he failed to learn it in the first place. He may fail to learn it in the first place if he is uncertain as to what it is he is supposed to learn. The diagnostic instruments used were designed to identify which of these types of failures the original lesson produced.

The original lesson was divided into seven segments. After seeing each segment, one group of 15 trial Ss was asked to indicate what they thought they were supposed to learn. A second group of 15 trial Ss was asked the same question at the conclusion of the entire lesson. These results pinpointed portions of the lesson that led to identification failures -- either identifying the wrong thing or failing to identify the right thing.

Students were also instructed to indicate how adequately the points they identified were taught. Some typical replies to these instructions are listed below:

--- "Although it was repeated many times the things on the board did not help."

--- "The film did not say how the force was increased."

--- "The word transmitted was not really stressed enough."

--- "He could have explained it better and more slowly."

--- "It wasn't explained fully enough because you couldn't tell what caused this."

--- "We know work as something different. It didn't explain it clearly enough."

--- "Why do you have to have the same weight applied to lift something?"

--- "It didn't explain why the man couldn't lift the car by himself and then with a piece of wood lift it with one finger."

Student diagnoses of lesson inadequacies in getting particular points across were used as one indicator of needed revision. Complementing the subjective student reports were the results of diagnostic achievement tests.

Achievement tests, reproduced in their entirety in Appendix B, were designed to assess both retention and transfer failures. For example, problems posed with numerical values identical with those used in the lesson were designed to measure retention. Problems with new values were designed to measure transfer. Other transfer items went further and required the application of principles of work, learned in the context of levers, to other machines, the pulley for example.

(b) assessment of response threshold. - Other diagnostic information was obtained from items requiring responses in differing modes. Items covering specific content that could be answered in multiple-choice or recognition format but not in constituted-response format provided additional results diagnostic of the instructional adequacy of a lesson. Where students were only capable of recognizing a correct answer (e.g., a definition of a concept), the lesson was revised so that they could produce a definition. Response mode differences thus provided evidence as to the response "strength" capabilities built into the original lesson

3. Evaluation tests

The tests to evaluate the instructional effectiveness of the original lesson and the two revised versions are reproduced in their entirety in Appendix C. Two forms of the test were prepared. Within each form, items were prepared specifically to test retention (test section labeled 'R') and to test transfer (test section labeled 'T').

Subjects

Subjects participating in this study were seventh graders drawn from five public and parochial schools. An intact class of thirty students took part in the diagnostic evaluation of the original lesson. One hundred and two students took part in the experimental evaluation of the three versions of the lesson on levers. Students were randomly assigned to one of the three conditions.

Procedure

1. Diagnosis of learning failures in original lesson.

In order to diagnose the shortcomings in an existing lesson, a sample class of thirty seventh-grade students viewed a kinescope of the lesson. As described earlier, half the group filled out questionnaire forms at the end of each of seven segments. The other half filled out the forms at the conclusion of the entire lesson. Questions on the form were designed to elicit student identification of what it was they thought they were supposed to be learning. They were also asked to indicate what it was in the lesson that failed to get across the particular points they had identified. Students were instructed that the purpose of their task was to help make revisions in the lesson so that it could be improved.

Following the presentation of the entire lesson diagnostic tests were administered.

2. Preparation of revised lessons.

On the basis of the results obtained in the tryout of the original lesson, the two revised lessons were prepared. As described both in the Introduction to this report and in the section of Materials, a variety of techniques were employed in an attempt to upgrade the effectiveness of the lesson. In light of this aim, no attempt was made to assess the effectiveness of particular techniques by building them into lessons and by leaving others out. The sole intent was to assess the usefulness of using a broad range of programming techniques in designing the stimulus features of the lesson while making no systematic provision for response practice.

3. Experimental comparison of three versions of lessons on levers.

Approximately two weeks before they saw the lessons on levers, students participating in this study took one form of the achievement test as a measure of their entering knowledge. Immediately following the presentations they took an alternate form of the test. Approximately one month later they took the original form of the test as a delayed posttest.

RESULTS

Following the random assignment of Ss to treatment conditions and the administration of the three experimental treatments, high and low I.Q. subgroups were identified for each treatment group. The median I.Q. was used as the dividing score. For purposes of data analysis, this resulted in a 3 x 2 design as illustrated in Figure 1.

	Treatments		
	retention version	transfer version	control version
High I.Q.			
Low I.Q.			

Fig. 1 Design for Analysis of Data

1. Analysis of entering behavior.

Two measures were obtained to compare the entering behavior of Ss who had been assigned to each of the three experimental conditions. These were pretest scores and I.Q. Analysis of variance for each of these measures indicated that there were no significant differences among the three treatment groups. The analysis of variance data appear in Tables 1 and 2, Appendix D.

2. Analysis of criterion behavior.

(a). Immediate posttest

Table 1 presents the results of the analysis of variance for total scores on tests administered immediately after the lesson presentations. As can be noted, there were significant differences among levels of both variables, I.Q. and treatments. Table 2 presents the means for the three treatment groups. On a test, in which 37 points were possible, the two experimental groups scored approximately 17 points; the control group almost 13 points. Both experimental versions differed significantly from the original lesson but not from each other.

TABLE 1

Summary of Analysis of Variance:
"Total" Scores on Immediate Posttest

	Source of Variation			
	I.Q.	Treatments	I.Q. x Treatments	Within
df	1	2	2	96
Mean Squares	412.01	209.45	24.98	27.68
F	14.89***	7.57**	—	

* significance at the 5% level
** significance at the 1% level
*** significance at the .1% level

TABLE 2

Mean "Total" Score for Three Treatments
on Immediate Posttest

	Retention Version	Transfer Version	Original Version
$\bar{X}$ =	17.09	17.32	12.91
S.D. =	5.32	5.53	5.97
N =	34	34	34

In subsequent analyses, test items testing for retention of specific content contained in the lessons and test items testing for transfer of principle to new situations were treated separately. Tables 3 and 4 present and summarize the analysis of results for the retention items only. As can be noted from the tables, on the retention items both the retention and transfer treatment groups differed significantly from the control but not from each other. The total number of points possible was 20.

TABLE 3

Summary of Analysis of Variance: "Retention" Scores on Immediate Posttest

	Source of Variation			
	I.Q.	Treatments	I.Q. x Treatments	Within
df	1	2	2	96
Mean Squares	40.16	50.94	3.10	15.25
F	2.63	3.34*	—	

TABLE 4

Mean "Retention" Score for Three Treatments on the Immediate Posttest

		Retention Version	Transfer Version	Original Version
$\bar{X}$	=	10.88	10.76	8.71
S.D.	=	3.80	3.80	4.11
N	=	34	34	34

The same kind of analysis performed for the transfer items only revealed similar results. Both revised versions of the lesson, the one designed to heighten retention and the one designed to heighten transfer produced significantly higher mean scores than the original version produced, but did not differ significantly from each other. Tables 5 and 6 summarize these findings. The total number of "transfer" points possible was 17.

TABLE 5

Summary of Analysis of Variance:
"Transfer" Scores on Immediate Posttest

	Source of Variation			
	I.Q.	Treatments	I.Q. x Treatments	Within
df	1	2	2	96
Mean Squares	194.91	54.75	12.12	$\boxed{9.19}$
F	21.20***	5.96**	1.3	

TABLE 6

Mean "Transfer" Score for Three Treatments
on the Immediate Posttest

	Retention Version	Transfer Version	Original Version
$\bar{X}$ =	6.21	6.56	4.21
S.D. =	3.70	3.17	3.10
N =	34	34	34

(b). Delayed posttest

Analyses similar to those just reported are available for tests administered on a delayed basis.

On the total test score no significant differences were discovered among the three treatment groups (see Table 3 in Appendix D for the summary of the analysis of variance). The means for the treatment groups were as follows: retention version - 11.91; transfer version - 12.71; and original version - 10.26.

Looking at the scores for retention items only, here also no significant differences were observed between treatment groups (see Table 4 in Appendix D for the summary of the analysis of variance). The means for the treatment groups were as follows: retention version - 8.70; transfer version - 8.06; and original version - 7.74.

For the transfer items only, significant differences were observed. (See Table 7). As can be noted in Table 8, the transfer version produced the highest mean transfer score, but the difference between it and the original version only was significant. Although the mean for the transfer version was larger than that for the retention version, the difference between them was not statistically significant.

TABLE 7

Summary of Analysis of Variance:
"Transfer" Scores on Delayed Posttest

	Source of Variation			
	I.Q.	Treatments	I.Q. x Treatments	Within
df	1	2	2	96
Mean Squares	2.20	28.89	11.73	7.21
F	—	4.01*	1.63	

TABLE 8

Mean "Transfer" Score for Three Treatments
on the Delayed Posttest

	Retention Version	Transfer Version	Original Version
$\bar{X}$ =	3.21	4.35	2.51
S.D. =	2.00	3.75	1.93
N =	34	34	34

DISCUSSION

The primary interest of this project has been to determine whether the application of programming techniques to a conventional television lesson can make it more effective. The method chosen to demonstrate whether or not this could be done was *not* the typical, experimental comparison of two independently created versions of a lesson covering the same material. Thus, it did *not* involve the preparation of two lessons, de novo, one in a conventional way, the other by using programming techniques.

Rather, programming techniques were used to *upgrade* an existing lesson. This was accomplished through a process of tryout and revision. By attempting to improve an existing lesson through the systematic identification of its weaknesses and through systematic efforts to overcome them, it is possible to specify more precisely the ways in which the two versions differ.

The results of this study thus have a bearing on two problems: (1) do the procedures for tryout and revision originated in this study provide a more systematic way of identifying weaknesses in lessons; and (2) do programming techniques produce revisions in a conventional lesson that make it more effective.

(a). *Procedures for tryout of an original lesson.*

The data reported in the preceding section cannot help us distinguish between the respective contribution made to the superiority of the revised versions of the lesson by the tryout procedures and by the programming procedures used for upgrading the lesson. Since overall performance level was raised roughly thirty percent over the original, it can be said that the *combination* of the two sets of procedures is not without merit. (We shall have more to say below about the inadequate, absolute level of achievement observed.) Without having at least two tryout procedures to compare (it was not the intent of this project to study this problem), the value of the procedures introduced must be made on a rational basis.

Typical pretesting procedures generally rely on some form of achievement testing. There tends to be little in such tests that performs a differential diagnostic function. The tests introduced in this study were primarily designed to fill this gap. This was accomplished through an analysis of the kinds of learning failures that are likely to occur.

As was pointed out earlier in the introductory section of this report, transfer cannot occur if retention is inadequate. Retention, in turn, cannot occur if the points to be learned cannot be identified. The diagnostic tests used were therefore designed to determine which of these different kinds of failures accounted for inadequate student performance. Revisions in the original lesson were then aimed at overcoming a particular kind of learning failure. In addition to this approach, systematic attention was also paid to the level at which the tryout sample of students could perform, i.e., whether they could only recognize a correct answer or whether they could produce it. Revisions also reflected these differing response thresholds.

While it was not the purpose of this study to do research on "pretesting" as an issue, it was possible while studying other issues to demonstrate effective means for improving the "pretesting" process.

(b). Applying programming principles to the design of the stimulus elements of a conventional TV lesson.

The primary purpose of the present project was to determine whether it was possible to develop a more effective conventional television lesson by applying programming techniques in the design of the stimulus elements. This was to be accomplished even though no systematic attempt was made to facilitate active responding. The stimulus elements of the two revised versions of the lesson on levers were redesigned to facilitate particular outcomes: heightened retention in one and heightened transfer in the other.

Data obtained from tests administered immediately following lesson presentation suggest that the two revised versions did not produce differential results. The "transfer" version did not produce better transfer than the "retention" version. The "retention" version did not produce better retention than the "transfer" version; but this is predictable since transfer could not have occurred without retention. Both versions did, however, excell the original. They surpassed the original by approximately thirty percent on "total" test scores, by approximately twenty percent on "retention" scores and by approximately forty percent on "transfer" scores. This improvement was not without its costs, however. Approximately twice the original learning time was required to produce it.

Redesign of the stimulus elements, with a multiplicity of programming principles as guidelines, thus resulted in substantial improvement over the original. But, the absolute performance level, as measured by programming standards was low. Students attained only fifty percent of the total possible.

On the delayed test, save for scores on the transfer subtest, neither the "retention" nor the "transfer" versions of the lesson were significantly superior to the original. On the "transfer" subtest the transfer version of the lesson produced a performance superior to the original (by approximately seventy percent). But here again the absolute level of attainment was low (only twenty-six percent of the total possible).

Had there been a third "revised" version in which active response had been required, we would be in a better position to assess just how much active responding would have added to a lesson benefiting only from effective stimulus design features. But there is sufficient prior research to testify to the value for learning of active responding. It seems perfectly justifiable to conclude on the basis of the results obtained here, that applying programming principles (e.g., use of contrasting examples for teaching discriminations needed for concept acquisition, etc.) to the design of the stimulus elements of a conventional lesson can enhance the quality of the lesson. But, without active practice of particular responses in the presence of the stimulus elements, there is likely to be a failure in bringing about adequate discriminative stimulus control. Further, without active responding delayed retention in particular seems to suffer.

CONCLUSIONS

It seems clear, on the basis of evidence produced here and elsewhere, that the success of programmed instruction depends both on effective design of the stimulus and on appropriate response practice. One school of programming, in fact, stresses the central role of response practice as a condition for bringing about stimulus control. Thus, from this point of view, selecting only one of two key features of programmed instruction is not likely to produce desired results. In an earlier study, Gropper and Lumsdaine (1961) demonstrated that active responding to conventional, non-programmed stimulus materials did not lead to more effective learning. In this study, the evidence appears to indicate that merely programming the stimulus elements is equally inadequate.

In evaluating the implications of the findings presented here, it should be kept in mind that they were based on one kind of learning task. Students were expected to acquire, retain and transfer a considerable number of concepts and principles. For this kind of goal, the learning experience created for students was inadequate. The conventional lecture format, albeit more effectively designed than is typically the case, was incapable of producing the desired level of mastery. On the other hand, other lesson objectives might benefit from redesigned, conventional lecture formats. If, for example, we wish to present a lesson designed to provide an introduction to or an orientation to a particular topic, we might wish to employ programming principles in the design of the stimulus elements. In such presentations, we rarely expect the viewer to produce any amount of detail we have offered him. Rather, we expect him to come away with one or two general ideas or even a general point of view. For this less demanding goal, concentration on the effective design of the stimulus materials (without requiring response practice) may be completely adequate.

The general conclusion to be drawn from this study is that programming principles applicable only to the stimulus elements of a conventional television lesson can produce significant improvements over more conventional "conventional" television lessons. When a large amount of detailed factual or conceptual material is to be learned, the magnitude of the improvement is likely to fall short of the usual standards set for programmed instruction. On the other hand, less demanding learning goals (e.g., general orientation) may be adequately met by applying programming principles to only one of the two key features of instructional sequences. Any more demanding goal would seem to call for intensive attention to both stimulus and response.

SUMMARY

Three versions of a television lesson on levers were compared. One was an existing lesson, used in previous research, that had been shown to produce inadequate levels of student achievement. The other two lessons were revised versions of the original. Revisions were made on the basis of prior pretesting of the original lesson. Special diagnostic tests prepared for this project were used to identify the kinds of learning failure produced by the original. These included failure: (a) to identify what was supposed to be learned; (b) to retain what was identified; and (c) to transfer what was retained.

Revisions in the lesson incorporated many features of programmed instruction. No attempt was made to single out a specific programming feature. Rather, changes reflected a global effort to upgrade the lesson. All changes made, however, revolved about the stimulus features of the presentation. No systematic effort was made to require active responding. Thus, the principal question to be answered in this study concerned the feasibility of using programming features to design a presentation while at the same time maintaining the "conventional" lesson format requiring no active response.

One revised version was designed to facilitate better retention than the original. This proved to be the outcome obtained. The second revised version was designed to facilitate better transfer than the original. This, too, proved to be the outcome obtained. However, the "retention" version did not differ significantly from the "transfer" version on any of the test measures observed.

Generally, it was concluded that concentration on only the stimulus, while neglecting the response pays attention to only one of two key elements. It can produce improvements over most typical lessons, but falls short of standards usually set for programmed instruction. This approach appears not to be useful in those situations where the student is expected to acquire, retain, and transfer large amounts of information. With lesser goals in mind, sequencing one or two main ideas in a lesson designed for general orientation or for imparting a point of view, the stimulus centered approach may prove to be adequate.

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Report #2 - An experimental comparison of a conventional TV lesson with a programmed TV lesson requiring active student response. (b)

Report #3 - An experimental evaluation of the contribution of sequencing, pre-testing and active student response to the effectiveness of "programmed" TV instruction. (c)

Report #5 - Issues in programming instructional materials for televised presentation. (d)

Report #7 - An overview. (e)

APPENDIX A

Scripts

Page No.

1. Script for Original Lesson on Levers. A-1

2. Script for Revised Retention and Transfer Versions of Lesson on Levers. A-7

Appendix A - Scripts

Script for Original Lesson on Levers

(Let's watch a man try to lift this automobile by himself. As much as he tries, he isn't strong enough to lift it. Let's see if two people can lift the automobile. Now two men are trying to lift the automobile together. Together they just manage to lift it a tiny fraction. Now let's watch and see if this long board can help the man to lift the automobile all by himself. Watch. The man is pressing down on one end of the board with just one finger and the automobile is being lifted quite a bit by the other end of the board. Let's watch it again. The man presses down on one end of the board with just one finger. And at the other end, the automobile is lifted up into the air.)

Today we're going to find out how the long board we just saw made it possible for the man to lift the automobile with just one finger. Remember without the long board he couldn't raise the automobile at all even with both arms, and, even with the help of another person, he still couldn't lift the automobile.

To help you understand how the long board helped the man to raise the automobile so easily, every now and then during the lesson I'm going to ask some questions and I'll pause to let you fill in the answers. Every time I ask a question, a question mark will appear on the screen like this ?/. Then I'll pause a second or two and let you give the answer. When you see the question mark on the screen, say the answer right out loud. See if you can say the answer out loud before I do. OK?

Now if we had a powerful machine like this crane, we could lift an automobile with it, couldn't we? The crane is a machine which performs or does work for us. What do we mean when we say a machine performs or does work? A machine performs work when it lifts a heavy load like this up from the ground. Any time we lift a load up we have performed ?/ (what) WORK. Did you say work out loud before I did?

When I slide this book from one side of the table to another, I do so by applying a push to it. When I lift the book up from the table I do so by applying a pull to it. Whenever I apply a push or whenever I apply a pull to any object like this book, I'm able to move it. Objects are moved when we apply pushes or ?/ PULLS.

Appendix A - Scripts

The objects are moved in the same direction as the push or pull. If I push this way, the book moves in the same direction as the push. If I pull in this direction, the book moves in the same direction as the pull. The book moves in the direction of the push or the pull. If I apply a push in this direction, the book moves in the same direction as the ?/ THE SAME DIRECTION AS THE PUSH.

Pushes and pulls have a name; they are called forces. Thus, when a push is applied to this book, we say that we have applied a pushing force to it. In the same way, when a pull is applied to this book, we can also say that we have applied a pulling ?/ (what) A PULLING FORCE. Forces either as a push or as a pull can make the book move. For example, the book was moved from down here to up here by applying a pulling force. We made the book move by ?/ (doing what to it) APPLYING A PULLING FORCE TO IT.

Whenever we apply a force to an object and the object moves in the same direction as the force - we have performed work. Let's define work in terms of forces. The amount of work we perform is equal to the force we apply times the distance the object moves. If I apply a pushing force of one pound to a book and the book moves two feet in the same direction as the force, I have performed two foot pounds of work. The amount of force applied times the distance the object moves is equal to the amount of ?/ (what that we perform) THE AMOUNT OF WORK WE PERFORM.

Let's do another example. Let's lift this two pound book. It takes a two pound force to lift a two pound book. Similarly, in order to lift a three pound book we need a ?/ (what size force) A THREE POUND FORCE. We need a force equal to the weight of a load in order to lift it. In order to lift a 2000 pound automobile, we need ?/ (what) A 200 POUND FORCE.

Getting back to books, how much work have we done when we lifted the two pound book two feet up ?/ (how many foot pounds of work) 2 x 2 = ? - FOUR FOOT POUNDS OF WORK. It takes a two pound force to lift a two pound book. Two pound force x two feet = four foot pounds of work. We compute the amount of work performed by multiplying the force that's applied times the (what that the object is moved) ?/ FORCE TIMES THE DISTANCE THE OBJECT IS MOVED.

What then do we mean by work (what does work equal) ?/ WORK EQUALS FORCE X THE DISTANCE AN OBJECT MOVES.

Appendix A - Scripts

Why do we use machines like the crane to do our work when they lift heavy loads? When loads are very heavy, very large forces are needed to lift them. As a matter of fact, we need a force that is as big as the weight of the load. If the load weighs 350 pounds we need a force of 350 to lift. Light loads require small forces to lift or move them. To lift or move large loads we need ?/ (what) LARGE FORCES.

Men aren't strong enough to apply a force that will be big enough to move a large or heavy load. He needs something that will increase forces for him so that they will be big enough. Therefore, machines are used to increase forces so that the forces will be big enough to move a heavy load. To move a heavy load we need a machine that will increase ?/ (what) A MACHINE THAT WILL INCREASE A FORCE. Machines help us because they (what do they do to forces) ?/ THEY INCREASE FORCES.

(The man pushed the board with just his finger. This means he applied a small force with his finger at one end of the board and the board increased or magnified the force so that it was big enough at the other end to lift the heavy car. Therefore, the board acted as a machine to increase a force.)

Machines help us by increasing forces. The straight board increased a force and therefore we can call it a ?/ MACHINE. The board that was used was rigid - that is, we couldn't bend it. The rigid board served as a simple kind of machine which we call a lever. Levers consist of objects which cannot be bent. In other words, they are rigid. Any rigid object can be used as a lever. But, to be called a lever a board must be ?/ RIGID. The board is placed on a fulcrum. The board can be pivoted like this around the ?/ (what) AROUND THE FULCRUM. The rigid board is pivoted around ?/ (what) THE FULCRUM. Why do we call the lever a machine? A lever is a machine because when we apply a force at one end we increase the force at the other end.

In addition to being increased, the force was transmitted from one end of the board to the other end. The man pushed on one end and the force was transmitted to the other end which lifted the automobile. Any lever transmits a force from one end to another. What happens to a force that is applied at one end ?/ IT IS TRANSMITTED TO THE OTHER END. A lever also increases forces.

A lever then does two things to forces. What two things does a lever do to forces? What does it do to the size of the force ?/ IT INCREASES THE FORCE.

The force goes from one end to the other. That means the lever does what to the force?/ TRANSMITS IT FROM ONE END TO THE OTHER. In addition to transmitting a force from one end to the other and increasing the force, a lever sometimes changes the direction of a force. When I push down here - there is a push up at the other end. The direction of the force was changed. A lever changes the ?/ (what of a force) THE DIRECTION.

I want you to make a lever in your classrooms now. Take a ruler, a pencil, and a book. Put the zero end to the left like this. Put a pencil under the two-inch mark like this. Put the book at the zero end. Now push down at the 12-inch end. It's easy to push the book up, isn't it? You applied a downward force at the 12-inch end and the direction at the other end was up. The push down is called the applied force and the upward push is called the lifting force. The push down is which force ?/ (the applied or lifting force) THE APPLIED FORCE IS THE PUSH DOWN. The upward push is therefore the ?/ THE LIFTING FORCE.

Put the book on the left end of your ruler again. Put the pencil under the two-inch mark and now push down at the right end or 12-inch end. It's easy to push down, isn't it? Move the ruler to the eight-inch mark. Push down at the 12-inch mark again. Was your downward applied force smaller, the same, or bigger than before ?/ IT WAS BIGGER.

We have just demonstrated the following principle: The closer the fulcrum is to the object we want to lift, the easier it is to lift it. What do we mean by easier? Easier means that we have to apply a smaller downward push at this end. When the fulcrum is close to the load, the applied downward force needed at this end is ?/ (large or small) SMALL. As the fulcrum moves away from the load, the applied downward force at this end in order to lift the load must be ?/ (what) GREATER. Put your ruler and book away now.

(When the fulcrum is close to the automobile the man is applying a downward force with just one finger and is able to lift the car at the other end. Let's see it with the fulcrum a little farther away from the car. Now, the man has to apply a force with his whole hand in order to raise the car. He has to bear down harder than before. Let's move the fulcrum even farther away. Now he needs both hands to apply the downward force and he has to work pretty hard to raise the car.)

Appendix A - Scripts

Let's see if we can explain why it's easier to push down on a lever and raise a heavy object when the fulcrum is nearer the load. We can show that the applied force times this length from the place the force is applied to the fulcrum is equal to the lift times this length from the place the lift occurs to the fulcrum.

Applied force times this length is equal to lifting force times this length. For example, I'm going to put a load of 15 pounds at this end of the lever, and I'm going to put the fulcrum two inches away from the load. All I need is an applied force of three pounds to lift the 15-pound load at the other end. Why? Let's look at our formula. The downward force is three pounds; this length is 10 inches. The load weighs 15 pounds and therefore we need a lifting force of 15 pounds to raise it. The upward force is 15 pounds. This length from the end to the fulcrum is two inches. Three pounds times 10 inches = 30 - fifteen pounds times two inches = 30. Thirty = thirty.

I'm going to move the fulcrum to the three-inch mark now. We still have a 15-pound load at this end. How much of a force do we need at this end to lift the 15-pound load at the other end? Let's figure it out. The 15-pound load times three inches equals 45. The fulcrum is three inches from this end and therefore it's nine inches from this other end. Therefore, on this side of the equation we have nine times ?/ (what) NINE TIMES FIVE. We need a five pound downward force or push to lift the 15-pound load at the other end. Length x load = length x applied force.

How can we tell how much of a push we'll need in order to lift a given weight or load? I apply the force at this end. This length is twice as long as this length. In order to make this equation equal, the applied force will have to be one-half the weight of the load that is lifted. This length is eight inches. This length is four inches. This one is twice as long as this one. Therefore, at this end we need only half the force. It takes just a 10-pound force to lift a 20-pound load. The equation comes out equal then. This length is twice as long as this one. This force is one-half this one.

If this length were two and this length were ten, this length would be five times as long. We would only need one-fifth the force to lift the 20-pound weight. Since the load is 20 pounds, we'd need a downward force of one-fifth of ?/ (one-fifth of how many pounds) 20 POUNDS. Therefore, we need a downward force of ?/ (one-fifth of 20 is how much) FOUR POUNDS.

But do we get something for nothing when we apply a small force and move a big load? Let's look at this example. Although we need only 10 pounds to lift a 20-pound load -- or one-half its weight, we have to apply this 10-pound force over a distance twice as long as that which the load covers. I have to push down two inches to raise this load one inch. I have to push down four inches to raise this load ?/ (how many inches) TWO INCHES.

So we don't get something for nothing. In order to raise a heavy load with a small amount of push -- I can only move the load a small distance. I have to apply a small force over a large distance in order to be able to raise a heavy load ?/ (over what kind of distance) A SMALL DISTANCE. The lever increases the push on the load -- but the load only moves a small ?/ DISTANCE. This is so because work in must equal work out -- applied force x distance must equal ?/ (what) LOAD TIMES THE DISTANCE.

(Even though the load moves just a little bit, machines are useful to us because without them we wouldn't be able to lift such heavy loads like the automobile.

Appendix A - Scripts

Script for
Revised Retention and Transfer Versions
of Lesson on Levers

Let's look at some examples of what is needed to make things move.

Retention	Transfer
1. The ball does not move until someone pushes it.	1. The model elevator rises because the cable pulls it up.
2. The door doesn't move until someone pulls it.	2. The ping pong ball does not move until the water pushes it.
3. The telephone doesn't get lifted until (someone) pulls it up.	3. The balloon (rocket) will not move until the thrust pushes it.
4. The box doesn't move until (someone) pushes it.	4. The bits of metal do not move until the magnet pulls them.
5. The sailboat does not move until air pushes it.	5. A stone falls because gravity pulls it down.

In all the examples you just saw, objects moved only when someone or something made them move. To make the objects move it took either a push or a (pause) pull.

If I don't push the wagon or if I don't pull the wagon, can it move? No, the wagon won't move unless I either (pause) push or pull it. The wagon does start to move if I apply a push to it -- like this, or if I apply a pull to it -- like this. Now we know why things move. They move when someone or something applies a push to them or applies a pull to them.

Scientists have given a special name to what we do when we apply a push to an object or when we apply a pull to an object. They say we apply a force to an object. But what exactly does apply a force mean?

Retention	Transfer
1. When a golfer applies a push to a golf ball with his club, scientists would say the club has applied a force to the ball.	1. When air applies a push to this model sailboard, scientists would say the air has applied a force to the sail.

Appendix A - Scripts

Retention (contd.)	Transfer (contd.)
2. When I pull a bucket up, I have applied a force to the bucket.	2. When the magnet pulls the iron filings up, the magnet has applied a force to the filings.
3. When I push a doorbell, my finger has applied a force to the doorbell.	3. When a hammer hits a nail, the hammer has applied a force to the nail.
I was able to make the box move because I applied a force to it.	I was able to make the golf ball move because I applied a force to the ball with a club.

Objects start to move only when you apply a force to them. An object like this golfball cannot start to move unless a force is applied to it. Whenever you apply a push or apply a pull to an object, scientists would say you are applying (pause) a force to the object.

In order to make the puppet move, we have to apply a force to it. To make the puppet move in an upward direction, in which direction must the force be applied? When I push this puppet up, the force is being applied to the puppet in an upward direction.

When I applied a downward push to the block, the force was applied in a downward direction. The direction of the force applied to the block was toward the (pause) left. In what direction is the force being applied now? The force is being applied to the block toward the (pause) right.

1. If I apply a force toward the East, the block will move toward the East.
2. In the same way, if I apply a force toward the West, the block will move toward the West.
3. If I apply a downward force to the handle, this handle will move (pause) down. The direction of the force and the direction of the movement are the same.

I want to move this box over in this direction from here to here. In which direction do I have to apply the force? In this direction, or in this direction? To move the box in this direction, I have to apply the force in this direction. An object moves in the same direction as the force.

Appendix A - Scripts

We've seen that in order to lift an object up, we have to apply an upward force to it. Let's find out how big the upward force has to be before it can lift something.

This meter measures how big a force is. When I pull on the meter, like this, the meter measures 5 lbs. because I am applying a 5-lb. force to the meter. When I pull harder, the meter measures 10 lbs. because now I am applying a 10-lb. force to the meter.

This box weighs 15 lbs. As you can see I am applying a 5-lb. force to the box. Although I am applying a force to the box, the box is not being lifted because the force is not big enough. I'll increase the force to 10 lbs. (pause) Now I am applying a bigger force than before, but the box still isn't lifted. The force is still not big enough. But, when I apply a 15-lb. force to the box, (pause) the force is big enough and the box is lifted. Since the box weighs 15 lbs., it takes a 15-lb. force to lift it.

This box weighs 10 lbs. In order to lift the box, I have to apply a 10-lb. force to it. (pause). This box weighs 20 lbs. In order to lift the box, I have to apply a 20-lb. force to it. (pause) If I applied less than a 20-lb. force, the box would not be lifted.

This box weighs 12 lbs. To lift the box, how much force will I have to apply to it? (pause) Because the box weighs 12 lbs., I have to apply a 12-lb. force to it in order to lift it. The amount of force applied to the box and the weight of the box have to be equal. If the amount of force is less than the weight of the box, could the box be lifted? No. In order to lift an object, the amount of force you have to apply to it must be equal to the weight of the object.

We have learned quite a bit about how things move. Let's go back and review them.

1. In order to move an object, what must we apply to it? (pause) a force to it. (pause)
2. You can apply a force to an object in two ways. You can either put it or (pause pull it.
3. The direction in which an object moves depends on the direction of the (pause) force. When we apply a force to an object, the object moves in the same direction (pause) as the force.

4. The amount of force needed to lift an object is equal to what? (pause) The amount of force needed to lift an object is equal to the weight of the object.

Retention

Let's watch a man try to lift this piano. As much as he tries, he isn't strong enough to lift it by himself. Now let's see if this long board can help the man lift the piano with just his thumb. Watch. The man is pressing down on one end of the board with just his thumb and the piano is being lifted quite a bit by the other end of the board.

Remember, without the long board he could not lift the piano at all. Today we're going to find out how the long board made it possible for the man to lift the piano by a force on the board with just one finger.

Transfer

Let's watch a man try to lift this automobile off the ground by himself. As much as he tries, he isn't strong enough to lift it. Now two men are trying to lift the automobile together. Even together they were not able to lift it off the ground. Now let's watch and see if this jack can help one man to lift the automobile off the ground all by himself. Watch. The man is pressing down on one end of the jack with just one hand and the automobile is being lifted off the ground by the other end of the jack.

Remember without the jack he could not lift the automobile at all, and even with the help of another person, he still couldn't lift the automobile. Today we're going to find out how the jack made it possible for the man to lift the automobile with just one hand.

When you hear the word machine, you probably think of complicated devices such as a crane which is used to lift things. But this straight board can also be used as a machine. The board is used as a machine any time it is used to lift objects. Let's lift this 20-lb. box with the board. With the board in this position, a 20-lb. box is lifted by applying a 20-lb. force at this end. When I make this side of the board shorter, the same 20-lb. box can be lifted by applying only a 10-lb. force (10 lbs.) at this end. I'll make this end even shorter, and see what happens. Now, I can lift the 20-lb. box by applying only 4 lbs. of force at this end.

Appendix A - Scripts

In order to lift the 20-lb. box by hand, I have to apply a 20-lb. force to it. By using the board and applying a force to this end, I can lift the same box, and I only have to apply a 4-lb. force. It is easier to apply a 4-lb. force than to have to apply a 20-lb. force.

In order to lift a 15-lb. box by hand, I would have to apply a 15-lb. force to the box. By using the board and applying a force to this end, I can lift the 15-lb. box and I only have to apply a 3-lb. force. It is easier to apply a 3-lb. force than to have to apply a 15-lb. force.

It is hard to lift a heavy object by hand because you have to apply a lot of force to the object. When I use this board, it becomes easy to lift the same object because I only have to apply a small force to the board. The board is called a machine because I can use a small force at one end to lift heavy objects at the other end. Since machines let us use small forces in order to lift heavy objects, machines make it easier for us to lift them.

Retention

In order to use a straight board as a simple kind of machine, what must the board be like? The board must be rigid. It must not bend.

The rigid board is placed on a fulcrum. The board is pivoted like this around the fulcrum. This pencil is also rigid. If we pivot it around a fulcrum like this, it can be used as a machine to lift an object. In order to be used as a machine, a board must be (pause) rigid. The rigid board is pivoted around a (pause) fulcrum. This kind of machine which pivots around a fulcrum is called a lever.

Transfer

In order to use an object as a simple kind of machine, what must the object be like? It must be rigid. It must not bend.

The rigid bar is placed on fulcrum. The bar is pivoted, like this, around the fulcrum. This bar can be used as a machine to li an object. This screwdriver is also rigid. If we pivot it around the edge of the can, like this, it can be used as a machine to lift the cover of the can. In order to be used as a machine, an object must be (pause) rigid. The rigid object is pivoted around a (pause) fulcrum. This kind of machine which pivots around a fulcrum is called a lever.

Appendix A - Scripts

When we use a lever to lift a load, we push down here and the lever pulls the load up at the other end. Since we will be talking more about the forces at the two ends, we should use their correct names. At this end, a downward force is applied to the lever by my hand. The downward force is called the applied force. At this end, an upward force is applied to the box by the lever. The upward force applied by the lever is called the lifting force. The push I give to the lever is called the applied force. The pull the lever applies to the box is called the lifting force. The push down is called (pause) the applied force. The pull up is called the (pause) lifting force.

Let's review what we have learned about the lever.

1. The lever can be used as a machine because we can lift a heavy load at one end even though the force we apply at the other end is (pause) small.
2. Any rigid board that pivots around a fulcrum is called a (pause) lever.
3. The downward push we apply to the lever is called the (pause) applied force.
4. The upward pull by the lever is called the (pause) lifting force. In the same way an upward push applied by the lever is called a lifting force.

If I wanted to lift this 5-lb. box by hand, how much upward force would I have to apply to the box? To lift a 5-lb. box by hand, you need a 5-lb. upward force. In order for the lever to lift the same 5-lb. box, how much lifting force will the lever have to apply to the box? In order for the lever to lift a 5-lb. box, the lever must apply a 5-lb. lifting force to it. The lifting force must be equal to the weight of the object.

This box weighs 10 lbs. In order for the lever to lift the box, the lever must apply a 10-lb. lifting force to it. The lifting force must be equal to the weight of the object. In order to lift this 15-lb. box, how much lifting force must the lever apply to the box? The lever has to apply a 15-lb. lifting force to it. To lift any object with a lever, the lever has to apply a lifting force which is equal to the weight of the object.

In order for the lever to be lifting the 15-lb. box like this, the lever must be applying a 15-lb. lifting force to it. But the force I am applying at this end is only 3 lbs. Therefore, it's easy to see that with a lever we get a lifting force which is bigger than the applied force.

Since this box weighs 20 lbs., the lifting force has to be 20 lbs. But, the applied force at this end is only 4 lbs. Therefore, with a lever we get a lifting force which is bigger than the applied force. If I pull down at this end with an applied force of just 2 lbs., will the lifting force at the other end be more than 2 lbs. or less than 2 lbs? At the other end of the lever, we get a force of 10 lbs. Thus, the lifting force of 10 lbs. is bigger than the applied force of 2 lbs.

The lever is pulling up with a lifting force of 12 lbs. Is the applied force at the other end more than 12 lbs. or less than 12 lbs.? The applied force is 3 lbs. Therefore, the applied force of 3 lbs. is smaller than the lifting force of 12 lbs. at the other end.

When we use a lever, even though the applied force may be small, we set a lifting force at the other end which is bigger than the applied force. Even though we apply only a small force here, because we get a big lifting force at the other end -- we can lift heavy loads. That's the reason we use levers to lift things. Levers let us lift heavy loads, even though we apply only a small force at this end.

Transfer

If I want to pick up this pile of books by hand, I apply an upward force to the books. I pull up and the books move up. But, when lifting books with a lever, I push down at this end and the lever pushes the books up at the other end. A lever is like a see-saw, when one end goes down the other end goes up. The lever changes the downward force at this end into an upward force at the other end.

As a result, the direction of the applied force and the direction of the lifting force are opposite. The lever changes the direction of a force from down at this end to up at the other end.

Let's review.

1. In order to lift an object, the lever must apply a lifting force that is equal to what? the weight of the object.
2. When we use a lever, we apply a small force at one end. At the other end, do we get a lifting force which is bigger or smaller than the applied force? We get a lifting force which is bigger than the applied force.
3. The direction of the applied force is downward but the direction of the lifting force is (pause) upward.

In order to get a 20-lb. lifting force at this end, I only have to apply a 10-lb. force at this end. What can I do so that I can use an applied force here which is even smaller than 10 lbs. and still get a 20-lb. lifting force at the other end?

Let's see how changing the position of the fulcrum makes it possible to use less and less applied force and still get the same amount of lifting force at the other end. Let's move the fulcrum closer to the load. We can still get a 20-lb. lifting force by applying only a 5-lb. force at this end. Let's move the fulcrum even closer to the load. We now get a 20-lb. lifting force even though I apply only a 2-lb. force at this end. By moving the fulcrum closer to the load, we can get the same amount of lifting force here even though we apply less and less force at this end.

Let's look at another example. When the fulcrum is in this position we can get a 12-lb. lifting force by applying only a 6-lb. force at this end. If I wanted to get the same amount of lifting force with an even smaller applied force than this, should I move the fulcrum away from the load or toward the load? (pause) The fulcrum should be closer to the load. Now, by applying only a 4-lb. force at this end, I can still get a 12-lb. lifting force. By moving the fulcrum closer to the load, we can get the same amount of lifting force even though we apply less and less force at this end.

When the fulcrum is close to the piano, the man is applying a downward force with just his thumb and is able to lift the piano at the other end. Let's see it with the fulcrum a little farther away from the piano. Now, the man has to apply a force with his whole hand in order to raise the piano. He has to bear down harder than before. Let's move the fulcrum even farther away. Now he needs both hands to apply the downward force and he has to work pretty hard to raise the piano.

Appendix A - Scripts

We have just demonstrated the principle that in order to lift a heavy load at the other end, the closer to the fulcrum is to the load the smaller the applied force at this end has to be.

When we want to lift a heavy load, there is a simple formula to figure out how small the applied force can be. There is a 20-lb. load at this end of the lever. In order to lift the 20-lb. load, we need a 20-lb. lifting force. The length from here to the fulcrum is 6 inches. On this side, the applied force is 4 lbs. The length from here to the fulcrum is 30 inches. Let's use this drawing to demonstrate the formula which lets us figure out how small the applied force can be. Here 20 x 6 = 120, and here 4 x 30 = 120. Look -- 120 is equal to 120. By multiplying lifting force times length on this side, we get 120; and, by multiplying applied force x length on this side we get 120. Lifting force x length on this side is equal to applied force x the length on this side. Therefore, our formula is lifting force x length = applied force x length.

Let's work another example on the same lever. Now there is a 10-lb. load at this end of the lever. In order to lift a 10-lb. load, we need a 10-lb. lifting force. The length from here to the fulcrum is 6 inches. On this side the applied force is 2 lbs. The length from here to the fulcrum is 30 inches. Let's look at our drawing again. Here, multiplying lifting force x length we get 10 x 6 = 60. Here, multiplying applied force x length we get 2 x 30 = 60. 60 equals 60.

Lifting force x length on this side is equal to applied force x length on this side. Therefore, our formula is (pause) lifting force x length equals applied force x length.

Transfer

By using our formula, we can find out how
big the applied force has to be in order to lift

By using our formula, we can find out how
big the applied force has to be in order
to lift this 10-lb. load on another lever.
Since we want to lift this 10-lb. load, the
lifting force on this side has to be how big?
The lifting force has to be 10 lbs.

Appendix A - Scripts

Retention

Here the length from the fulcrum to the load is 8 inches. Therefore 10 x 8 = 80.

On this side of the fulcrum, the board is 40 inches long. On this side of the fulcrum, applied force x length must also equal 80. Thus what times 40 will equal 80? 2 x 40 = 80. How much must the applied force be? (pause) The applied force must be 2 lbs. Let's see if by applying a 2-lb. force here the lever can lift a 10-lb. load?

A 10-lb. lifting force is produced here -- when all I applied here was a 2-lb. force. The way we were able to figure out what the applied force had to be was from the formula. Lifting force x length = applied force x length.

Let's try another example. We want to lift a 12-lb. load. Therefore the lifting force has to be 12 lbs. The length of the lever from here to the fulcrum is 1 foot. 12 x 1 = 12. The length from here to the fulcrum is 3 feet.

On this side of the fulcrum, applied force x length must also equal 12. What x 3 will = 12? 4 x 3 = 12. What must the applied force be? The applied force must be 4 lbs. Let's see if it works.

Transfer

A man can easily lift this heavy box off the floor, if he uses this hand truck. The wheels of the hand truck act as the fulcrum. When he applies a downward force to the handle - the platform at the other end of the handtruck will apply an upward force to the box. The hand truck is another example of a lever.

Let's work with this model handtruck. Since we want to lift this 15-oz. load, the lifting force has to be how big? The lifting force has to be 15 oz. By using our formula, we can find out how big the applied force on the handle has to be in order to lift this 15-oz. load. Here the length from the edge of the platform to the fulcrum is 2 inches, 15 x 2 = 30. The length from the tip of the handle to the fulcrum is 6 inches long. On this side of the fulcrum, applied force x length must also = 30. Thus what x 6 will = 30? 5 x 6 = 30.

Here 15 x 2 = 30, lifting force x length = 30. Here 5 x 6 = 30, applied force x length = 30. How much must the applied force on the handle be? (pause) The applied force must be 5 oz.

Let's see if by applying a 5-oz. force here the handcart can lift the 15-oz. load. A 15-oz. lifting force is produced here -- when all I applied here

Retention (contd.)

A 12-lb. lifting force is produced here when all I applied here was a 4-lb. force. 12 x 1 = 4 x 3. You can tell how much applied force will be needed if you remember the formula, lifting force x length = applied force x length.

Transfer (contd.)

was a 5-oz. force. The way we were able to figure out what the applied force had to be was from the formula, lifting force x length = applied force x length.

Let's try another example. We want to lift a 12-oz. load. Therefore the lifting force has to be 12 oz. The length of the platform is 2 inches. 12 x 2 = 24, lifting force x length = 24. The length of the handle is 8 inches. On this side of the fulcrum, applied force x length must also = 24. What x 8 = 24? 3 x 8 = 24. What must the applied force be? The applied force must be 3 oz. Let's see if it works. A 12-oz. lifting force is produced here when all I applied here was a 3-oz. force. 12 x 2 = 24 and 3 x 8 = 24. You can tell how much applied force will be needed if you remember the formula, lifting force x length = applied force x length. Lifting force x length = applied force x length.

We can find out how hard or easy it is to lift an object just by measuring how long the two sides of the lever are. This side is 1 ft. long and this side is 2 ft. long. 1 ft. - 2 ft. As you can see, this side is 2 times longer than the other side.

Each of these blocks weighs 1 lb. In order to lift the 4-lb. load it takes a 4-lb. lifting force. We got a 4-lb. lifting force here, even though only a 2-lb. force was applied here. The lifting force is two times bigger than the applied force. When this length is 2 times longer than this length, the lifting force here will be 2 times bigger than the applied force here.

Let's look at another example using the same lever. This side is 2 times longer than this side. In order to left this 6-lb. load it takes a 6-lb. lifting force. I got a 6-lb. lifting force here by applying only a 3-lb. force here. The lifting force is 2 times bigger than the applied force. When this side is 2 times longer than this side, the lifting force here will be 2 times bigger than the applied force here. By finding out that this side is 2 times longer than this side, we were able to figure out that the lifting force would be 2 times bigger than the applied force.

Let's look at another example using a different lever. This side is 30 inches long and this side is 6 inches long. 30 inches is 5 times longer than 6 inches. Therefore, with this lever we will get a lifting force at this end which will be 5 times bigger than the applied force. By applying a 1-lb. force here, we can get a lifting force of 5 lbs. By measuring the two sides of the lever, we found that this side was 5 times longer than this side. Therefore, the lifting force here became 5 times bigger than the applied force here.

On this lever, this side is 3 ft. long and this side is 1 ft. long. 3 ft. is 3 times longer than 1 ft. Since this side is 3 times longer, the lifting force at this end will be how many times bigger than the applied force? It will be 3 times bigger. The lever will apply a lifting force 3 times bigger than the applied force because this side is 3 times longer than the other side. If the applied force is 3 lbs., how big will the lifting force be? The lifting force will be (pause) 9 lbs. Since this side is 3 times longer than the other side, how big will the lifting force be if I apply a 2-lb. force here? (pause) The lifting force is 6 lbs. or 3 times bigger than the applied force. By finding out how much longer this side is compared to the other side we can figure out how many times bigger the lifting force will be than the applied force.

Before we go on and learn more about the lever, let's review what we just learned.

Point 1. The closer the fulcrum is to the load, the easier it is to lift a heavy load.

Point 2. We learned the formula that lifting force x length = (pause) applied force x length.

Point 3. Just measuring the length of both sides of the lever, we can tell how many times bigger the lifting force is than the applied force.

Appendix A - Scripts

This man is doing work everytime he lifts a box. In physics, to do work means something special. Let's find out what a physicist means when he talks about doing work.

When I apply an upward pull to this box, I am applying a force to the box. But, the force is not strong enough to move the box. Even though I have applied a force to the box, I have not performed any work because the box did not move. Now I am applying more force to the box but I still haven't done any work because the box still has not moved. Now, I'm applying a big enough force and the box moves. That's what the physicist means when he uses the word to do work. You do work when you apply a force and the object moves. Even though I'm applying a force, if the object doesn't move I have not performed work.

Retention

To lift this block up a distance of 2 ft., the man keeps applying a 5-lb. force to the block all the way from here to here for a distance of 2 ft. To lift this block up a distance of 6 inches, he keeps applying a 3-lb. force to the block from here to here for a distance of 6 inches. To move this box a distance of 3 ft., he keeps applying a force of 20 lbs. from here to here for a distance of 3 ft.

In all three examples, work was performed because the man applied a force and the object moved.

Let's measure <u>how much</u> work the man performed when he lifts the blocks. When the man lifts this 5-lb. block up a distance of 2 ft., he has performed 18 in. lbs. of work: 2 ft. x 5 lbs. = 10 ft. lbs.

Transfer

To lift this 3-lb. block up a distance of 6 inches, the rope keeps applying a 3-lb. force to the block from here to here for a distance of 6 inches. Work was performed. To lift this 5-lb. block up 2 ft., the rope keeps applying a 5-lb. force to the block all the way from here to here for a distance of 2 ft. Work was performed. To move this 20-lb. block a distance of 3 ft., the rope keeps applying a force of 20 lbs. from here to here for a distance of 3 ft.

In all 3 examples, work was performed because a force was applied to an object and the object moved.

Let's measure how much work was performed when the blocks were lifted. To lift this block, the rope applied a 20-lb. force for a distance of 3 ft. 3

3 ft. x 20 lbs. = 60 ft. lbs. of work

Retention (contd.)

To lift this block, he applied a 10-lb. force for a distance of 6 inches. 6 in. x 3 lb. = 18 in. lbs. of work. To move this box, he applies a 20-lb force over a distance of 3 ft. 3 ft. x 20 lbs. = 60. ft. lbs. He has done 60 ft. lbs. of work.

How many ft. lbs. of work did the man do when he applied a 12-lb. force and lifted the block 1 ft.? 1 ft. x 12 lb. = 12 ft. lbs. of work.

Transfer (contd.)

When the rope lifts this 5 lb. block for a distance of 2 ft., 10 ft. lbs. of work was performed. 2 ft. x 5 lbs. = 10 ft. lbs. To move this block, the rope applied a 3-lb. force over a distance of 6 in. 6 in. x 3 lbs. = 18 in. lbs. of work.

How many ft. lbs. of work was performed when the rope applied a 12-lb. force and lifted the block 1 ft.? (pause 1 ft. x 12 lbs. = 12 ft. lbs. of work.

Here is a bucket of paint that weighs 7 lbs. I am going to lift the can up to this shelf a distance of 3 ft. To lift the bucket I have to apply a force of 7 lbs. To put it on the shelf, I have to move it a distance of 3 ft. How much work have I performed? (pause) 3 ft. x 7 lbs. = (pause) 21 ft. lbs. of work. Distance x force = amount of work done.

When the physicist talks about work, he means the amount of force x the distance an object moves. Work = force x distance.

Do we get something for nothing when a lever lets us apply a small force and still lift a big load? Let's look at this example.

Using the lever, I can lift a man by applying a small force with my thumb. I am using a very small force at this end to lift the heavy man at the other end. But, in order to raise the man just a little bit, I have to push down a long distance at this end, all the way to the floor.

I can raise a heavy load by applying a small force here but, I have to push down a long distance -- while the man is raised only a short distance. When I pushed down on a lever, I did work because I applied a force for a distance. Work = applied force x distance. At the other end, the lever did work because it a applied a lifting force for a distance. Work = lifting force x distance. We can measure the amount of work done at each end of a lever.

Retention

Let's use this diagram to demonstrate the amount of work done at each end of a lever.

This is where the lever was. This is where it is now. At this end, a 10-lb. force is applied for a distance of 5 inches. Since a 10-lb. force was applied for a distance of 5 inches, we multiply 5 inches x 10 lbs. to get 50 in. lbs. of work. Applied force x distance = the amount of work we put into the lever. At the other end, this is where the lever was. This is where it is now. The 25-lb. load is lifted a distance of 2 inches.

Here, a 25-lb. lifting force was applied for a distance of 2 inches. 2 inches x 25 lbs. = 50 in. lbs. of work. Lifting force x distance = the amount of work put out by the lever.

Transfer

When I try to lift the lid off the paint can with my fingers, I cannot apply a strong enough force, but I can pry the lid off when I use a screwdriver as a lever. The edge of the can acts as the fulcrum. The push down on the handle is the applied force, and, the push up on the lid is the lifting force. When a screwdriver is used to pry things off, it is used as a lever.

Let's use this diagram to demonstrate the amount of work done at each end of a screwdriver.

This is where the handle was. This is where it is now. At this end, a 10-lb. force was applied for a distance of 5 inches. Since a 10-lb. force was applied for a distance of 5 inches, we multiply 5 inches x 10 lbs. to get 50 in. lbs. of work. Applied force x distance = the amount of work we put into the screwdriver. At the other end this is where the tip of the screwdriver was. This is where it is now. The 25-lb. lifting force lifted the lid a distance of 2 inches. Here, a 25-lb. lifting force pushed the lid up for a distance of 2 inches. 2 inches x 25 lbs. = 50 in. lbs. of work. Lifting force x distance = the amount of work put out by the screwdriver. 50 in. lbs. of work was done on this side and 50 in. lbs. of

Retention (contd.)

50 in. lbs. of work was done on this side and 50 in. lbs. of work was done on this side. Lifting force x distance here = applied force x distance here. So, the amount of work we put in at the applied end equals the amount of work that the lever puts out at the lifting end. Work in = work out.

Transfer (contd.)

work was done on this side. Lifting force x distance here = applied force x distance here. So, the amount of work we put in at the applied end equals the amount of work that the screwdriver puts out at the lifting end. Work in = work out.

Let's try another problem. In order to lift a 12-lb. load a distance of 2 inches, I must apply a 4-lb. force for a distance of 6 inches. At this end, 6 inches x 4 lbs. = 24 in. lbs. At this end, 2 inches x 12 lbs. = 24 in. lbs. 24 in. lbs. of work put into the lever = 24 in. lbs. of work put out by the lever. Again work in = work out because the lifting force x distance here must equal the applied force x distance here.

When the lever lifts this 20-lb. load for a distance of 1 ft., the amount of work thelever does equals 1 ft. x 20 lbs. or how many ft. lbs.? (pause) 20 ft. lbs. Work = lifting force x distance. 20 ft. lbs. of work had to be done on this side too. Since a 10-lb. force was applied at this end, how far down did the lever go? (pause) In order to do 20 ft. lbs. of work, a downward force of 10 lbs. must be applied for a distance of (pause) 2 ft. Here 1 ft. x 20 lbs. = 20 ft. lbs. of work. And here, 2 ft. x 10 lbs. = 20 ft. lbs. of work. 20 ft. lbs. put into the lever = 20 ft. lbs. put out by the lever. Again, work in = work out.

Work is performed at both ends of the lever. The lifting force x distance at this end equals the applied force x distance at the other end. We were able to get a lifting force of 20 lbs. here, even though only a 10-lb. force was applied here. Since work in has to equal work out, we do not get something for nothing. You will notice that the force had to be applied for a distance of 2 ft. here just to get the load up 1 ft. at this end.

As you can see, the fulcrum has been moved closer to the load. If I want to lift this 15-lb. load 1 ft., the amount of work the lever has to do will equal 1 ft. x 15 lbs. Work = lifting force x distance. I have to do 15 ft. lbs. of work at this side too. If I apply a 5-lb. force at this end, how far down will I have to push this side in order to do 15 ft. lbs. of work? I must apply a force of 5 lbs. for a distance of (pause) 3 ft. 1 ft. x 15 lbs. = 3 ft. x 5 lbs. We can get a lifting force of 15 lbs. here, even though I only apply a 5-lb. force here. Since work in has to equal work out, we don't get something for nothing. You will notice I have to push down 3 ft. just to get the load up 1 ft. at this end.

In order to lift a heavy load by applying a small force, I have to apply the small force for a long distance. And I can only move the load up a short distance. So we use a small force but we have to apply it for a long distance.

Let's review what we mean by work and what it means when we use a lever.

Point 1. We do work whenever we apply force over a distance. Work = force x distance (push down on lever).

Point 2. When we use a lever, work in must = (pause) work out. The formula for work in = work out is lifting force x distance = (pause) applied force x distance.

Point 3. We can apply a small force at one end and raise a heavy load at the other end. We do not get something for nothing because we have to apply the small force over a long distance to raise the heavy load a short distance. However, even though the man is lifted just a little bit, levers are useful to us because without them we wouldn't be able to lift heavy loads at all.

APPENDIX B

Diagnostic Tests

Page No.

1. Form I B-1
2. Form II. B-8
3. Form III B-15

Form I

Name ____________________

Group __________ Date __________

SEGMENT I - A

1. If you apply an upward force to a box, what will happen to the box?

____

____

____

____

2. What do we mean when we say that we "apply a force" to an object?

____

____

____

____

3. The direction in which an object moves depends on

____

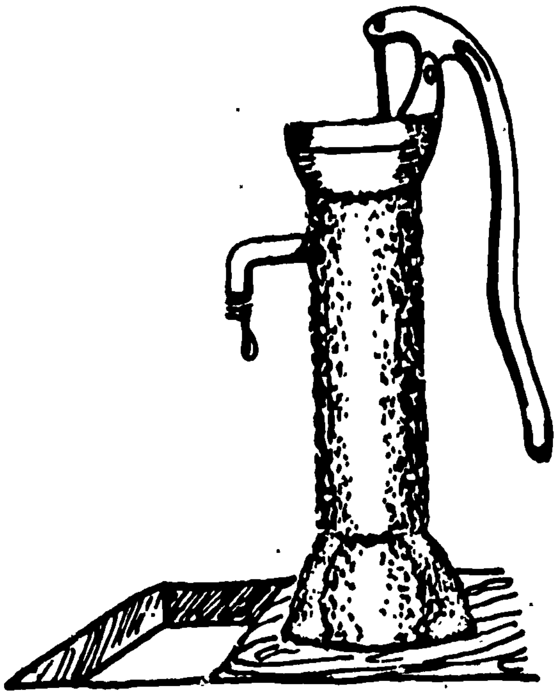
____

SEGMENT II - A

1. What do we mean when we say we have performed "work?"

2. In order for a steam shovel to lift 100 pounds of dirt into the air, what must the steam shovel do to the dirt?

3.



A man pumped up 6 lbs. of water from the bottom of the well which was 10 ft. below the ground. How much work did he perform?

SEGMENT III - A

1. It's easier to raise a heavy load of dirt with a steam shovel than to try to lift it by hand because

2. Why is it harder to raise a heavy load than to raise a small load?

3. What do we mean when we say a machine "makes work easier?"

SEGMENT IV - A

1. When we apply a force at one end of a lever, what is the lifting force like at the other end?

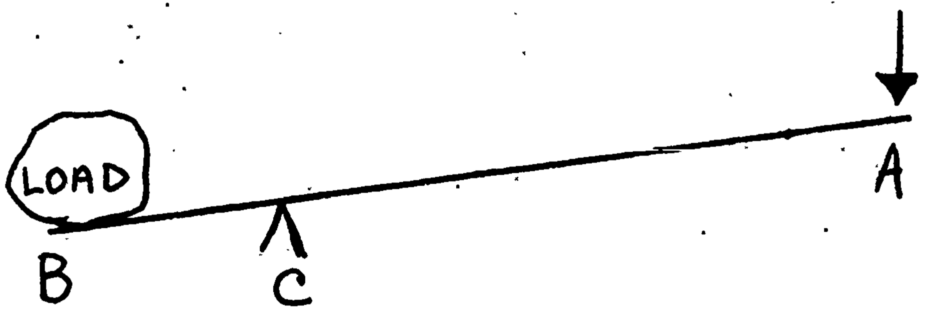
   (a) ____

   (b) ____

2. If we want to use a board as a lever, what must the board be like?

   ____

3.



   (a) What is the part at C called? ____________________

   (b) Why is a lever called a machine?

   ____

   ____

   ____

SEGMENT V - A

1. The pushing down force at one end of a lever is called the ______________ force.

2. The upward push given by a lever to the load is called the ______________ force.

3. What should you do to the fulcrum of a lever in order to make it easier to lift a heavy load?

____

4. When using a lever, what do we mean when we say that we can make it "easier" to lift a heavy load?

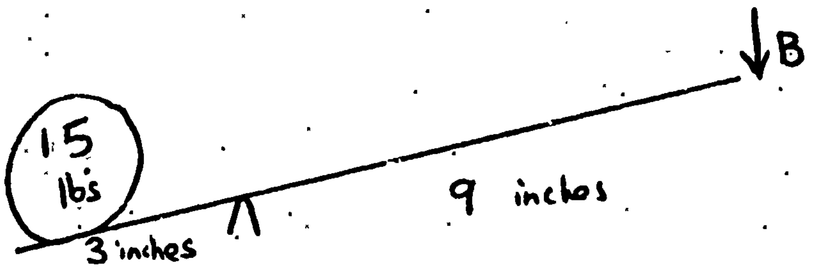
____

____

SEGMENT VI - A

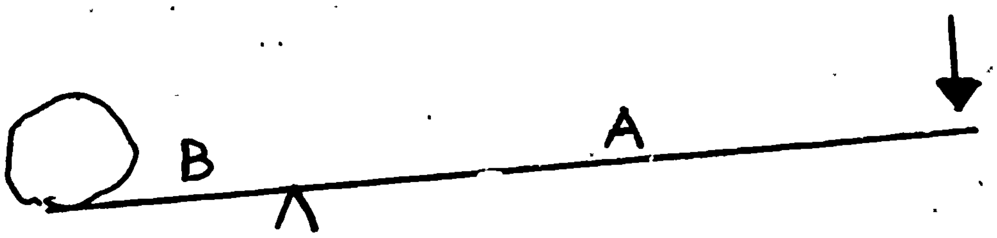
1. What is the formula you use to find out how much applied force is needed to lift a load with a lever?

2.



How much force do we need at B to lift the 15-lb. load?

3.



If part A is three times longer than part B, what will the size of the lifting force be compared to the applied force?

SEGMENT VII - A

1. Explain how we don't get something for nothing when we apply a small force and lift a big load.

____

____

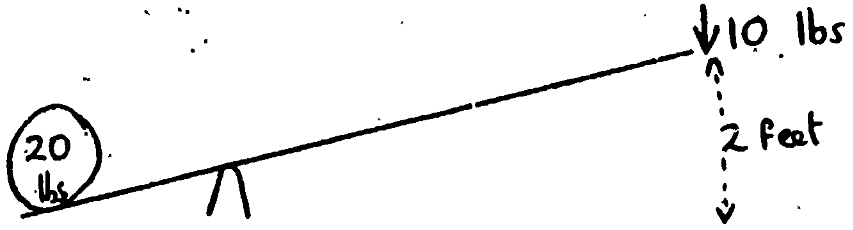
____

2. What is the formula that tells us how great a distance we can lift a load when we apply a force to a lever?

____

____

3.

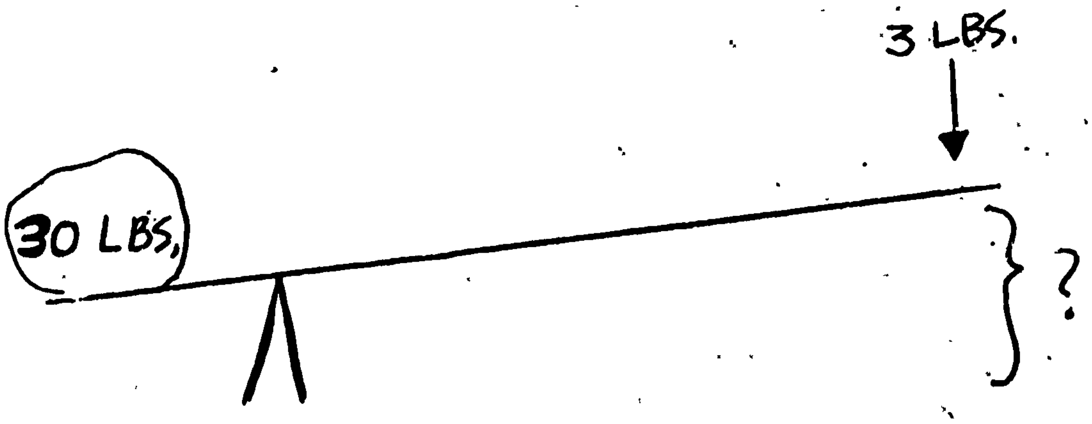


If I push down 2 feet with an applied force of 10 lbs., how high will the load be raised?

____

4. How far down will this lever have to be pushed to lift the rock one foot?

____



Form II

Name ____________________

Group ________ Date __________

SEGMENT I - B

1. A man applied a force to a large rock. We didn't see him apply the force, but we did see the rock move. How could we tell in which direction the force was being applied?

2. When the Egyptians were building the pyramids, they had to lift heavy slabs of stone in order to get them to the top of the pyramid. In order to move the slabs up, what did they have to do?

3. Write down three examples from your everyday life which show different ways in which you apply a force to objects.

SEGMENT II - B

1. How can we figure out how much force has to be applied to an object in order to lift it?

2. What would you need to know to figure out how much work is being done when an elevator takes people up from the ground floor to the top floor?

3. What is the difference between the amount of force we apply to an object to move it and the amount of work we do in moving it?

SEGMENT III - B

1. A man using a pulley, applied a 10-lb. force to the ropes and was able to lift a 100-lb. load. What did the pulley do to make this possible?

2. It's almost impossible for men to lift large slabs of concrete weighing several tons, by hand.

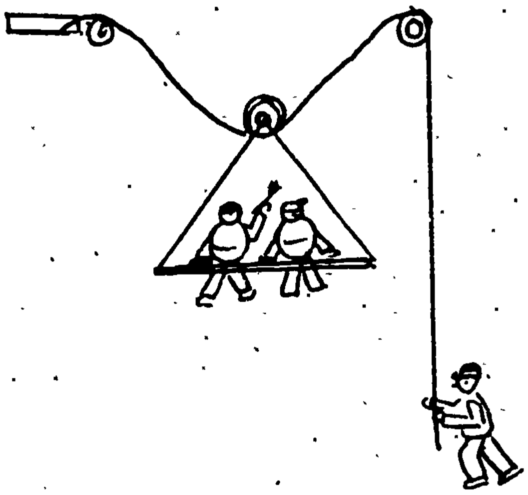
   (a) Why?

   (b) How do machines make it possible to lift such weights?

3. To lift a 50-lb. box by hand, we must apply a 50-lb. force to it. How much force can we apply to a lever and still lift the 50-lb. load?

SEGMENT IV - B

1.



A man used a pulley to raise two other men sitting on a platform. In order for one man to raise two men, what must the pulley do?

____

____

2. The man pulls down on a pulley rope and yet another rope lifts a load up. In order for this to happen, what must the pulley do to the force the man applied?

____

3. Why do we call a lever a machine?

____

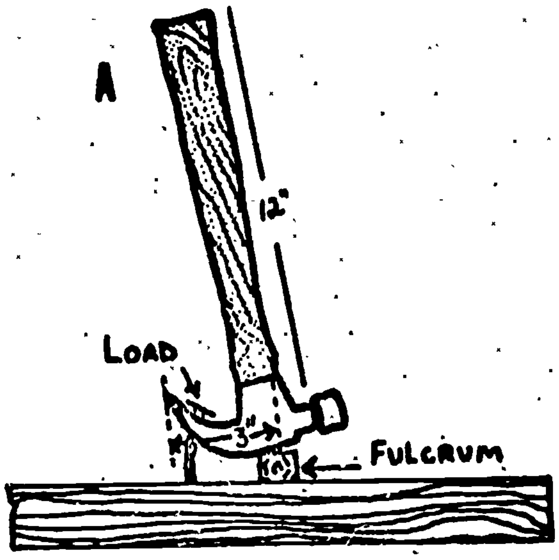
____

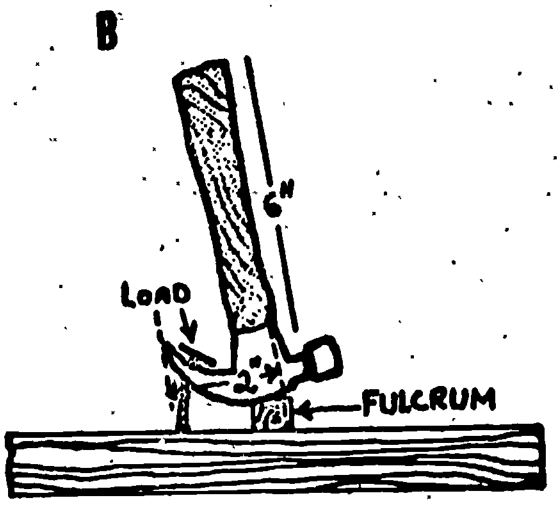
____

SEGMENT VI - B

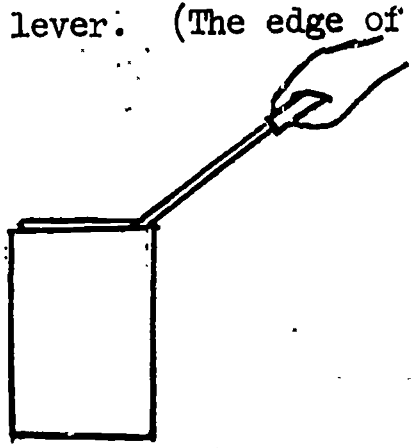
1a. If a man applied a 10-lb. force to hammer A, how many lbs. of lifting force would be applied to the nail? ____________________

1b. If 10 lbs. of force was applied to hammer B, how many lbs. of lifting force would be applied to that nail? ____________________





2. When you use a screwdriver to pry off the lid of a paint can, the screwdriver is being used as a lever. (The edge of the can is the fulcrum.)



You know that you need a lifting force of 60 lbs. to get the lid off the can. What else do you need to know in order to figure out how much force you will have to apply to the handle?

____

____

Form II

SEGMENT V - B

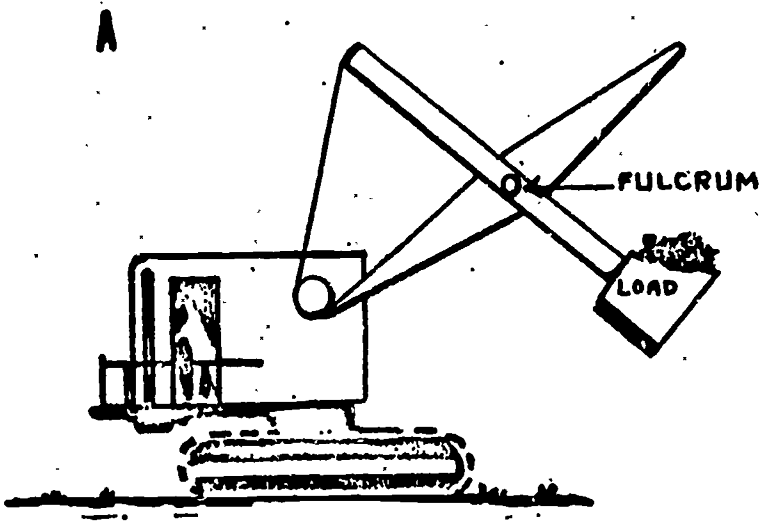
1. Which steam shovel below can lift a heavy load with less applied force?

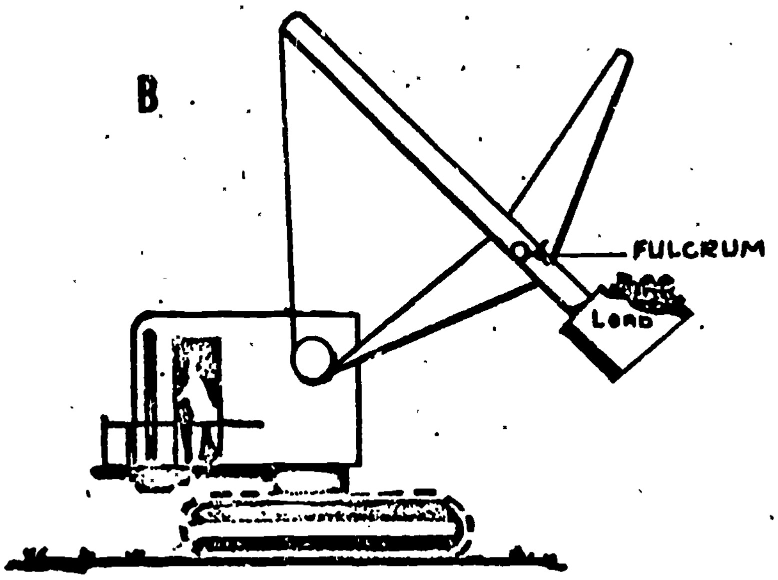
____

How did you decide which shovel can lift a heavy load with less applied force?

____

____



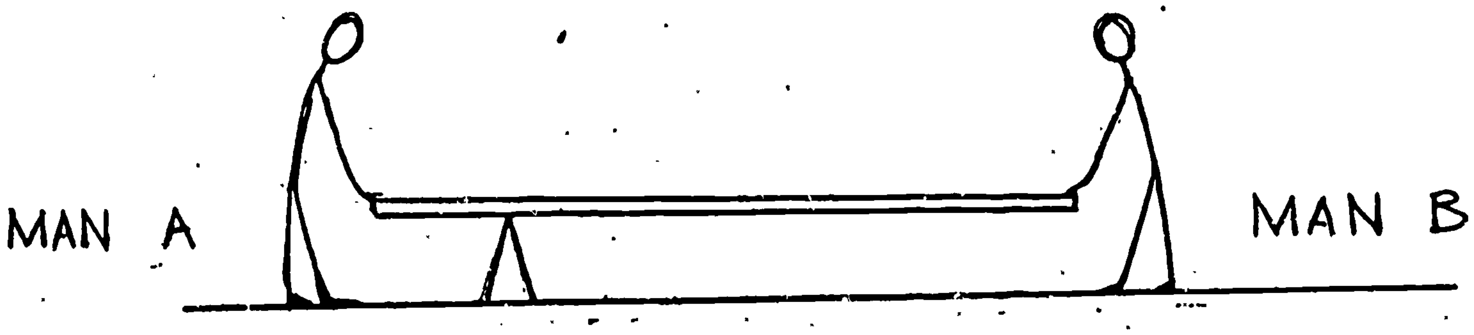


2.

(a) Two men are having a contest to see which one can push his own end of the board down to the ground. Which man will win when both men apply equal forces?

Man _______ Why? ______________________________

____

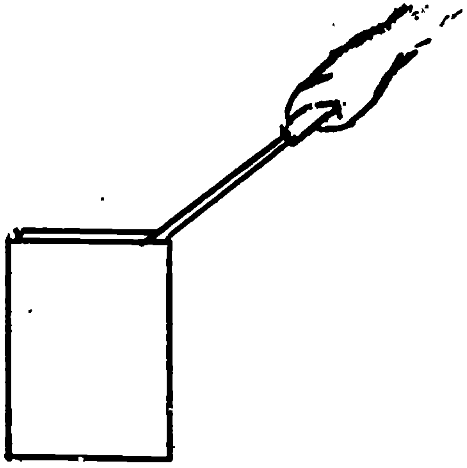


(b) In order to make the contest between the two men to come out a tie, what should we do to the lever?

____

SEGMENT VII - B

1.



It takes a very large force to pry the lid off a paint can. It can be done with a screwdriver, by applying only a small force to the handle. However, we don't get something for nothing.

Besides being small, what else must the force applied to the handle be like?

2. When you use a pulley, you can apply a small force and still raise a large load. What will you have to do to the pulling rope in order to be able to use just a small force?

Why is this necessary?

3. It takes a 50-lb. lifting force to pry a rock up out of the ground with a crow bar. In order to raise the rock 1 inch, you have to push the handle down 10 inches. How much applied force will be needed?

Form III

Name ____________________

Group __________ Date __________

SEGMENT I - C

1. Put an X next to the sentences below which are examples of a force being applied to objects:

_____ a. boxer punching a man in the chest.

_____ b. two teams playing tug-of-war with a rope.

_____ c. a horse pulling a wagon.

_____ d. man hitting a baseball.

_____ e. three men pushing a stalled car.

2. When an object moves, the direction it moves will be

_____ a. opposite to the direction of the force.

_____ b. the same as the direction of the force.

_____ c. perpendicular to the direction of the force.

_____ d. none of the above.

3. A car will move <u>forward</u> if: (check <u>all</u> the correct answers)

_____ a. a tow truck in front pulls it.

_____ b. another car in back pushes it.

_____ c. the engine applies a forward force to the wheels.

_____ d. the gears are in reverse.

_____ e. the engine is running with the gears in neutral.

SEGMENT II - C

1. In order for a steamshovel to lift 50 lbs. of dirt 10 ft. into the air, the shovel must

_____ a. apply 10 lbs. of force to the dirt.

_____ b. apply 50 lbs. of force to the dirt.

_____ c. apply 500 lbs. of force to the dirt.

_____ d. do 50 ft.-lbs. of work.

_____ e. do 100 ft.-lbs. of work.

2. A man lifts three suitcases from the ground onto a platform which is one foot high. Each of the suitcases weighs 10 lbs.

(A) To each suitcase he had to apply a force of

_____ a. 1 lb.

_____ b. 3 lbs.

_____ c. 10 lbs.

_____ d. 30 lbs.

(B) The total amount of work he performed was

_____ a. 3 ft.-lbs.

_____ b. 10 ft.-lbs.

_____ c. 30 ft.-lbs.

_____ d. 60 ft.-lbs.

3. Work equals

_____ a. weight times force.

_____ b. force times direction.

_____ c. force times distance.

_____ d. direction times distance.

_____ e. weight times direction.

SEGMENT III - C

1. When we use a machine, it lets us lift

_____ a. smaller loads than before.

_____ b. only the same sized load as before.

_____ c. larger loads than before.

2. Which of the following are examples of a machine making work easier? (Check as many answers as are correct.)

_____ a. a man using a pulley is able to lift three other men

_____ b. a 150-lb. boy balancing another 150-lb. boy on a seesaw

_____ c. a man prying a 200-lb. rock loose by applying a 20-lb. force to a crow bar

_____ d. a man couldn't pull a nail out of the wall with a 10-lb. force; he applied the same amount of force to a claw hammer and pulled the nail out

3. Machines are used to lift large loads because (check as many answers as are correct)

_____ a. men aren't able to apply large enough forces by hand.

_____ b. machines take small forces and makes them bigger.

_____ c. machines lessen the weight of the load.

_____ d. the lifting force produced by the machine is equal to the weight of the load.

_____ e. none of the above is correct.

SEGMENT IV - C

1. A small downward force at one end of a lever lifts a heavy load at the other end. This means that the lever has (check as many answers as are correct)

_____ a. changed the direction of the force at the other end.

_____ b. decreases the strength of the force at the other end.

_____ c. produced a bigger lifting force at the other end.

_____ d. all of the above answers are correct.

2. Put an X next to all the objects below which are being used as a lever.

_____ a. seesaw

_____ b. a board supported at both ends

_____ c. a board resting on one rock

_____ d. a thin, flexible twig

_____ e. a claw hammer used to pull a nail out

3. One man using a pulley can raise three men on a platform. This means that the pulley

_____ a. made the weight of the load smaller.

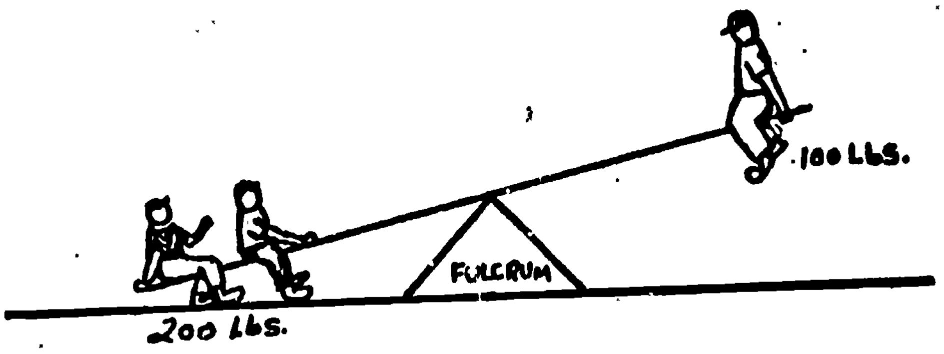
_____ b. reduced the applied force.

_____ c. did nothing to the applied force.

_____ d. made the lifting force bigger.

SEGMENT V - C

1.



One boy on one end of a seesaw can lift two boys on the other end if the two boys move

_____ a. closer to the fulcrum.

_____ b. further away from the fulcrum.

_____ c. to the extreme end of the seesaw.

2. If you move the fulcrum away from the load you will need

_____ a. a bigger applied force.

_____ b. a smaller applied force.

_____ c. the same amount of applied force.

3. When we say it becomes "easier" to lift a load, we mean that

_____ a. the load gets lighter.

_____ b. more lifting force is applied.

_____ c. less lifting force is applied.

_____ d. less applied force is needed.

_____ e. more applied force is needed.

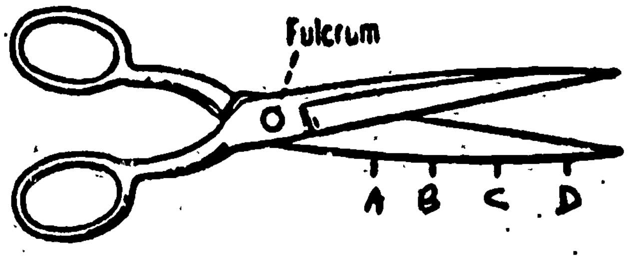
4. It is easier to cut through a piece of thick cloth with a pair of scissors if the edge of the cloth is placed at

_____ a. A

_____ b. B

_____ c. C

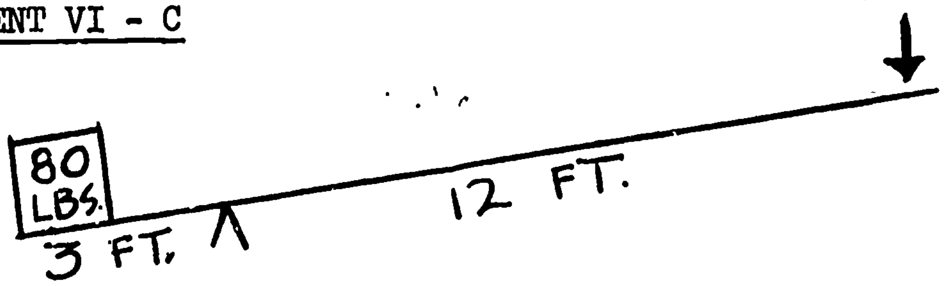
_____ d. D



Form III

SEGMENT VI - C

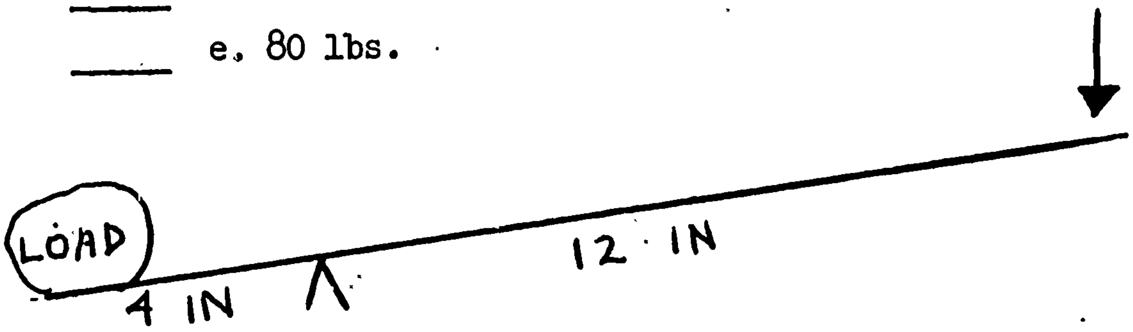
1.



The applied force required to lift this load is

_____ a. 3 lbs.
_____ b. 4 lbs.
_____ c. 12 lbs.
_____ d. 20 lbs.
_____ e. 80 lbs.

2.

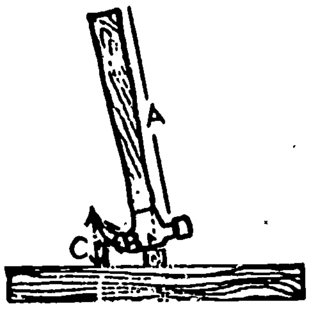


When we use this lever, the applied force will lift a load

_____ a. 1/4 as big.
_____ b. 1/3 as big.
_____ c. 3 times bigger.
_____ d. 4 times bigger.
_____ e. of equal size.

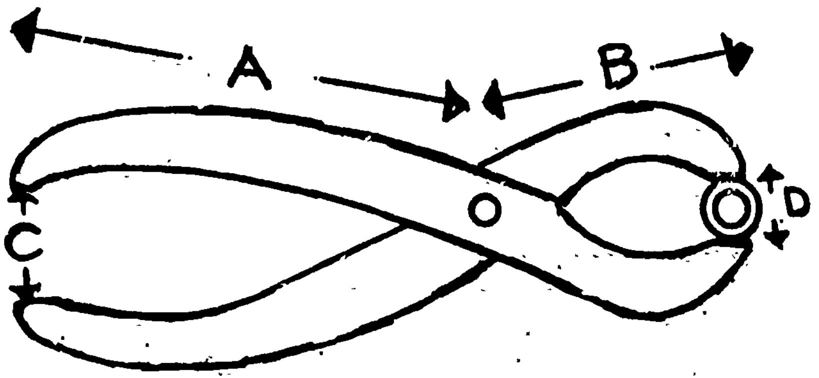
3. Put an X next to <u>all</u> the answers which have the information you'd need to know to pull out the nail <u>with the hammer</u>.

_____ a. Distance A
_____ b. Distance B
_____ c. Distance C



4. To figure out how many times bigger the force on the ring is than the force on the handle, which lengths would you compare?

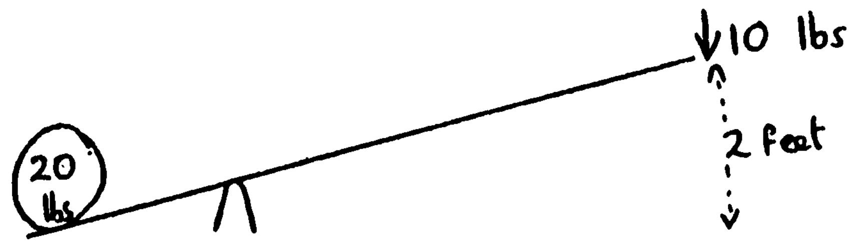
_____ a. A
_____ b. B
_____ c. C
_____ d. D



Form III

SEGMENT VII - C

1.



If I push down 2 feet with an applied force of 10 lbs., how high will the load be raised?

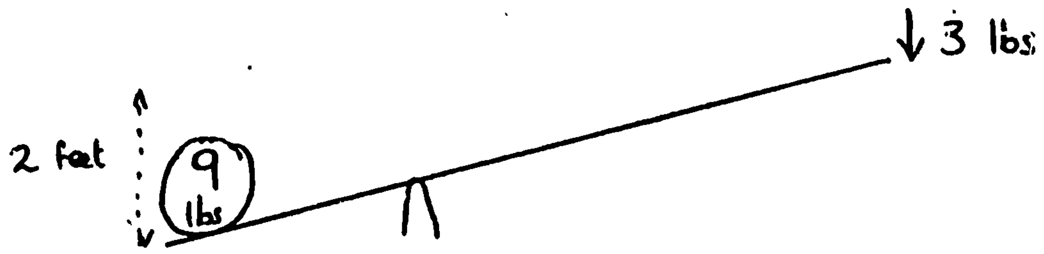
_____ a. 1/2 ft.

_____ b. 1 ft.

_____ c. 2 ft.

_____ d. 5 ft.

2.



To raise the 9-lb. load 2 feet, I would have to push down with an applied force of 3 lbs. for a distance of

_____ a. 2 feet.

_____ b. 3 feet.

_____ c. 4-1/2 feet.

_____ d. 6 feet.

_____ e. 9 feet.

3. When you lift a heavy load by applying only a small force to the lever

_____ a. you push down a short distance and the load is raised a short distance.

_____ b. you push down a long distance and the load is raised a short distance.

_____ c. you push down a short distance and the load is raised a long distance.

_____ d. you push down a long distance and the load is raised a long distance

APPENDIX C

Evaluation Tests

Page No.

1. Form I. C-1
2. Form II C-6

Form I

Name ______________________________ Pre ____ Post ____ Delayed ____

School ______________________________ Group ______

Grade ____________

MACHINE LESSON

Form 1 - R

1. In order to lift an object off the ground, the force a man applies to it must be

(a) ____

(b) ____.

2. What does a scientist mean when he says it's easier to lift a load with a machine than to lift it by hand?

____

____

Why is it easier with a machine?

____

____

____.

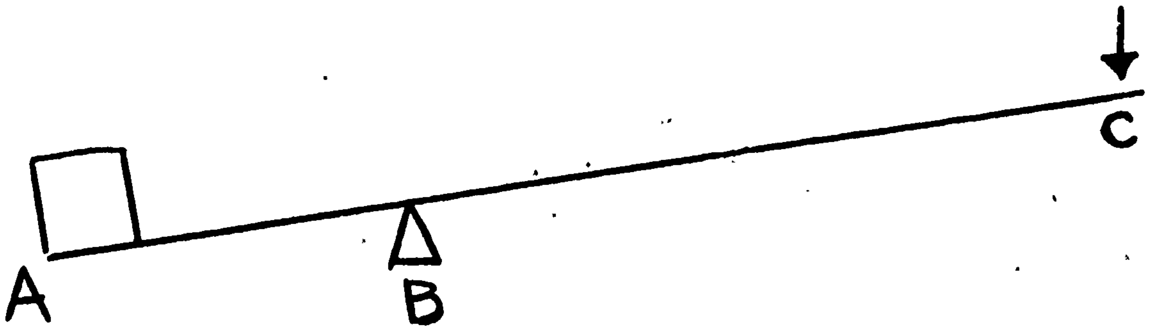
3. A man wants to use a straight board as a lever. What must the board be like?

____

What must the man do with the board?

____

4.



What is part B called? ______________________

What is the downward force at C called? ______________________

What is the upward force at A called? ______________________

5\.

(a) In order to lift a load, how much lifting force must a lever apply to the load?

____

____

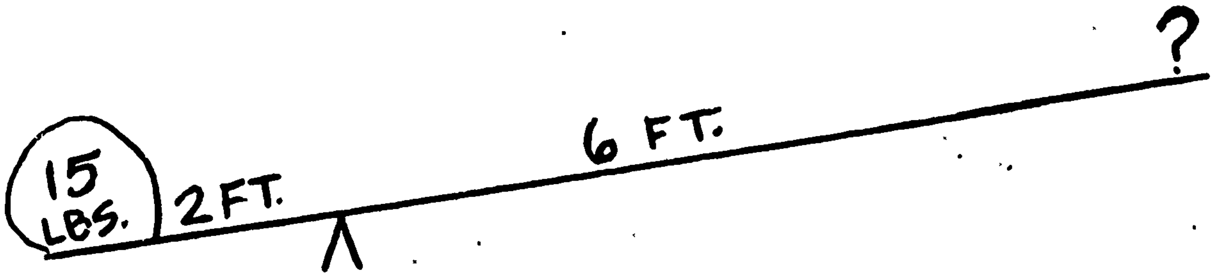
(b) Using the word "force" in your answer, tell why a man uses a lever to lift a load?

____

____

____

6\.



(a) We want to lift a 15-lb. load with a lever. What is the formula for figuring out what the applied force should be?

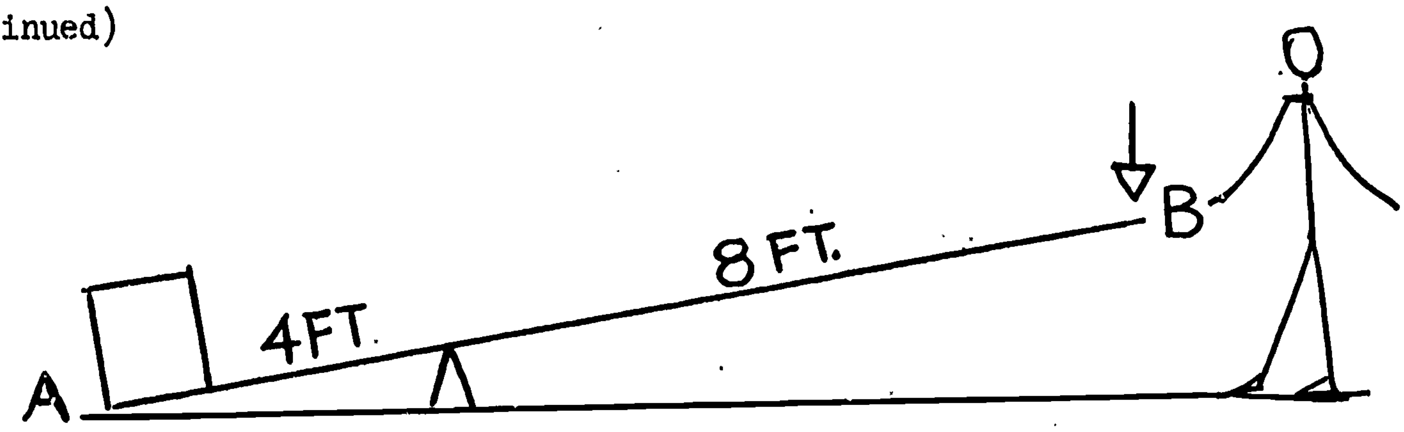
____

____

(b) Using the formula, figure out what the applied force is.

____

6. (continued)



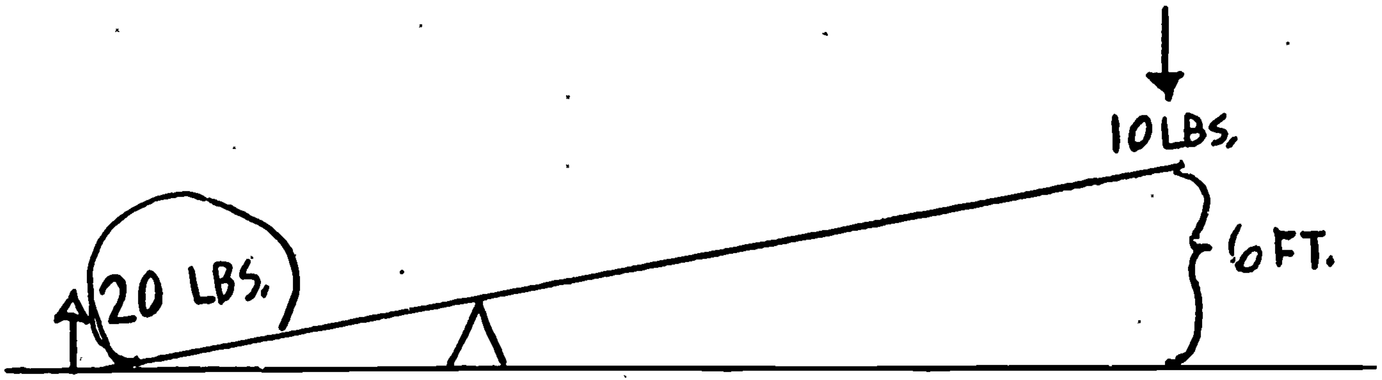
(c) Which force is bigger, A or B? ________

(d) How many times bigger than the other force is it? ____________

7. A man kept applying a 20-lb. force to a huge boulder, but he couldn't budge it. How much work did he do?

____

8.



If the applied force is 10 lbs. and the lever is pushed down 6 ft., how high will a 20-lb. load be lifted?

____

Form 1 - T

9. If a scientist said that steam in a railroad engine "applied a force" to the wheels, what would he mean?

____

10. The direction in which a baseball sails through the air depends on

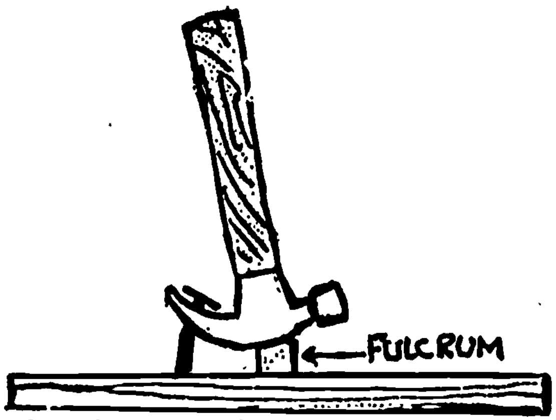
____.

11. A pulley is one type of machine used to lift heavy objects. You have two pulleys to choose from. How would you decide which of the two pulleys to use?

____

____

12.



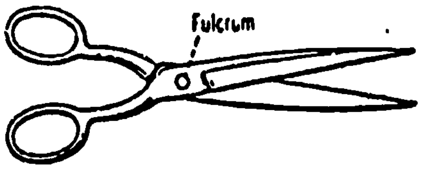
You use the claw end of a hammer to pull a nail out from a board. The force you apply to the hammer and the force the hammer applies to the nail are different from each other in amount and in direction. Exactly how are they different?

(a) ____
(amount)

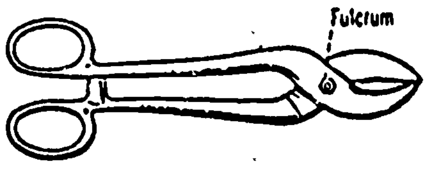
(b) ____
(direction)

13.

A



B



You need to cut something. Which pair of scissors, A or B, would make it easier for you?

____

Why? ____

14. A man pumped up 6 lbs. of water from a well which was 10 ft. below the ground. How much work was performed?

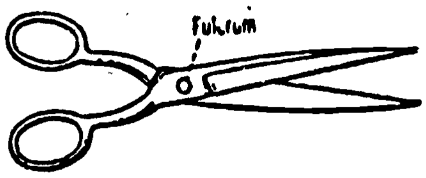
____

What is the formula for figuring out how much work was done?

____

____

15.



A pair of scissors acts as a lever when you use it to cut things. When using a pair of scissors, work in = work out. What does this mean?

____

____

____

16. When you use a pulley, you can use a <u>small</u> applied force and still raise a <u>large</u> load.

(a) How far down will you have to pull the rope and how high will the load be raised?

____

____

(b) Explain why you gave the answer you did.

____

____

____

E-24

Form II

Name ____________________ Pre ____ Post ____ Delayed ____

School ____________________ Group _____

Grade __________

MACHINE LESSON

Form 2 - R

1. A scientist pushed an object and then pulled it. What special words would the scientist use to tell you what he did to the object?

____

2. In order to lift a 25-lb. box off the floor, what must a man do to it?

____

____

3. You have two levers: A and B. It's harder to lift the same load with lever A. What do we mean when we say it's harder?

____

____

____

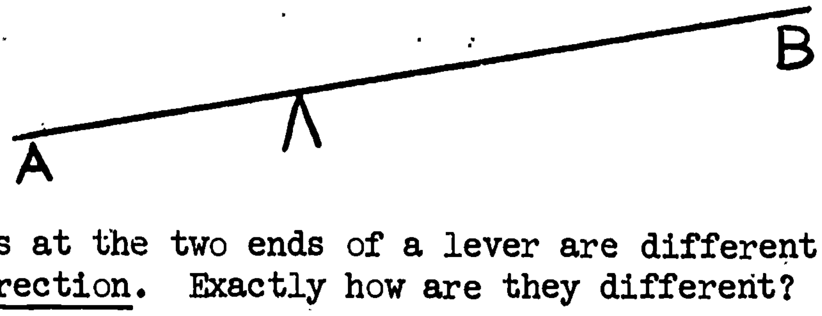
4. A man wants to use a straight board as a lever. What must the board be like?

____

What must the man do with the board?

____

5.

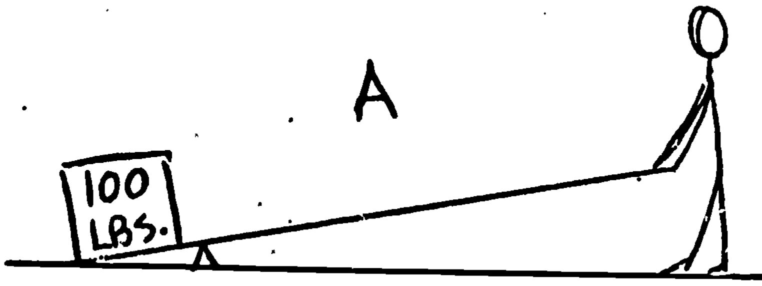


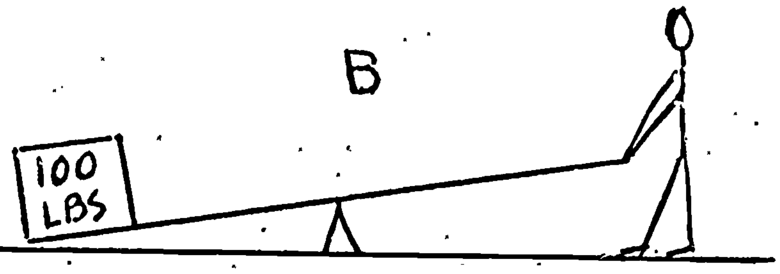
The forces at the two ends of a lever are different from each other in amount and in direction. Exactly how are they different?

(a) ____
(amount)

(b) ____
(direction)

6.





Which man will have to apply a <u>bigger</u> downward force, A or B? ________

Why? ______________________________

____

7. (a) What does a scientist mean when he uses the word "work?"

____

____

(b) What is the formula for figuring out how much work is done?

____

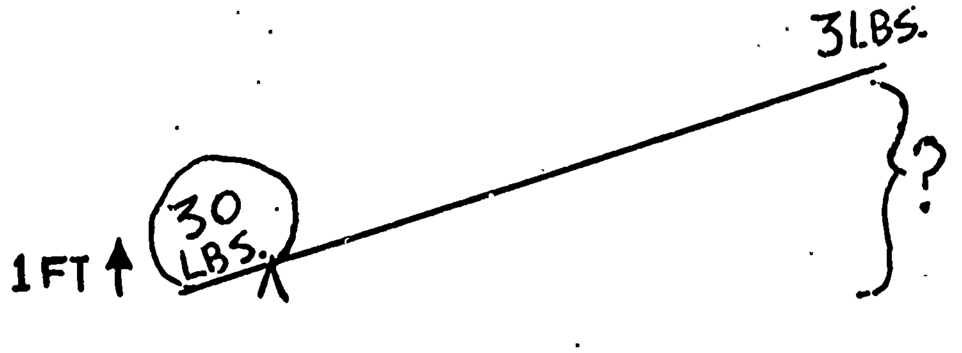
____

8. What is the formula that tells us how <u>high</u> we can lift a load when we use a lever?

____

____

9.



(a) How far down must this lever be pushed to lift the rock one foot? ________

(b) Why must it be pushed down that much?

____

____

Form 2 - T

10. A steam shovel applied an upward force to a huge boulder, but the boulder didn't get off the ground. What would you tell someone about the force that the steam shovel applied to the boulder, so that he would understand why it wasn't lifted off the ground?

11. You have to lift a very heavy box. What would you do to make it easier for yourself in lifting it?

Why would this make it easier?

12. A pulley is a machine just as a lever is a machine. We pull down on one rope and another rope lifts a heavy load up.

The downward pull is called the ____________________.

The upward pull is called the ____________________.

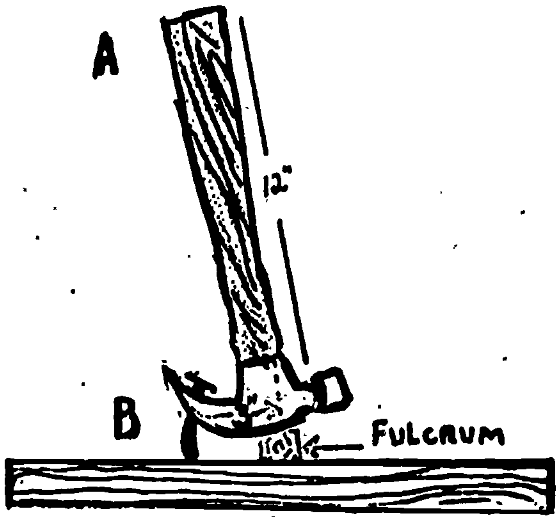
13.

(a) In order to lift a load, how much lifting force must a pulley apply to the load?

(b) Using the word "force" in your answer, tell why a man would use a pulley to lift a load.

Form II

14. A hammer is used as a lever.



(a) Which is bigger, the force at A or the force at B? ________

(b) How many times bigger than the other force is it? ________

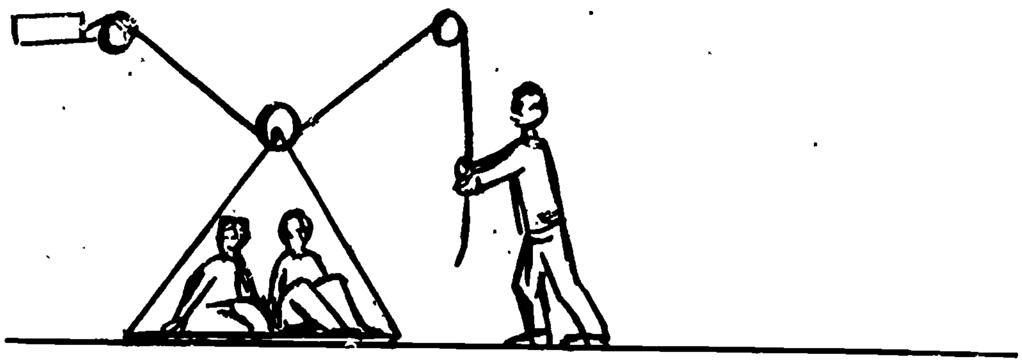
(c) If the force at B is 60 lbs., what is the force at A? ________

(d) What is the formula for figuring out how much force is needed at A?

____

____

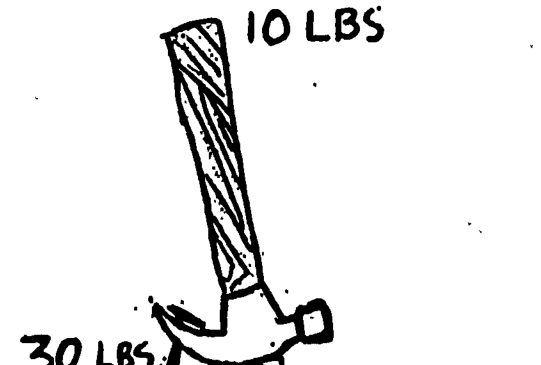
15.



A man kept applying a 100-lb. force to a pulley, but he couldn't raise two men sitting on a platform. How much work did he do?

____

16.



You apply a 10-lb. force to the hammer and the hammer lifts the nail with a force of 30 lbs. You pull the hammer down six inches. How high will the nail be raised?

____

APPENDIX D

Additional Results

Page No.

1. Table 1 Summary of Analysis of Variance: "Total Scores on Pretest. D-1
2. Table 2 Summary of Analysis of Variance: I.Q. D-1
3. Table 3 Summary of Analysis of Variance: "Total Scores on Delayed Posttest D-2
4. Table 4 Summary of Analysis of Variance: "Retention" Scores on Delayed Posttest. . D-2

TABLE 1

Summary of Analysis of Variance:
"Total" Score on Pretest

Source of Variation				
	I.Q.	Treatments	I.Q. x Treatments	Within
df	1	2	2	96
Mean Squares	21.66	14.89	27.77	$\boxed{6.58}$
F	3.29	2.26	4.22*	

* significance at the 5% level
** significance at the 1% level
*** significance at the .1% level

TABLE 2

Summary of Analysis of Variance:
I.Q.

Source of Variation				
	I.Q.	Treatments	I.Q. x Treatments	Within
df	1	2	2	96
Mean Squares	3660.01	1.26	12.01	$\boxed{25.94}$
F	12.95***	—	—	

TABLE 3

Summary of Analysis of Variance:
"Total" Score on Delayed Posttest

	Source of Variation			
	I.Q.	Treatments	I.Q. x Treatments	Within
df	1	2	2	96
Mean Squares	145.92	52.72	55.72	22.14
F	6.59*	2.38	2.52	

TABLE 4

Summary of Analysis of Variance:
"Retention" Scores on Delayed Posttest

	Source of Variation			
	I.Q.	Treatments	I.Q. x Treatments	Within
df	1	2	2	96
Mean Squares	92.25	8.30	32.95	14.24
F	6.48*	—	2.31	