REPORT RESUMES

ALMOST NO EXPERIMENTAL EVIDENCE AVAILABLE SUBSTANTIATES
THE CLAIM THAT THE BEST POSSIBLE WAY OF TEACHING SCIENCE IS
BY BASING THE PRESENTATION UPON THE STRUCTURE OF A SCIENCE.
RESEARCH IN THIS AREA HAS BEEN CLOUDED BY THE FAILURE TO
CLEARLY SPECIFY THE ORDERED SEQUENCE OF MATERIALS AND
INADEQUATE TESTS TO DETERMINE--(1) IF THE DESIRED ORDER
EXISTS, AND (2) IF RANDOM ARRANGEMENT OF MATERIALS PRODUCES A
DIFFERENT ORDER. IN THE STUDY RELATED HERE, THERE WERE THREE
OBJECTIVES. THE FIRST OBJECTIVE WAS TO PRODUCE A SET OF
PROGRAMMED MATERIALS WRITTEN TO CONFORM TO A DEFINITION OF
ORDER, AND AN ALTERED VERSION OF THESE MATERIALS. THE SECOND
OBJECTIVE WAS TO DEVISE MEANS OF DETERMINING IF--(1) THE TWO
VERSIONS EFFECTIVELY TAUGHT THE SUBSTANTIVE CONTENT, AND (2)
THE STRUCTURED UNIT WAS TRULY STRUCTURED AND DIFFERED FROM
THE UNSTRUCTURED UNIT. THE THIRD AIM WAS TO INSTITUTE AN
EXPERIMENT WHICH WOULD PROVIDE DATA FOR--(1) MEASURING THE
EFFECTIVENESS OF THE TWO UNITS, (2) DECIDING IF THE UNITS
WERE STRUCTURED OR NOT, AND (3) EXAMINING SOME EFFECTS OF
STRUCTURE ON MEASURES OF TRANSFER AND ACHIEVEMENT.
APPROXIMATELY 200 FOURTH, FIFTH, AND SIXTH GRADERS SERVED AS
SUBJECTS. THERE IS A FULL DISCUSSION OF THE RESULTS AND OF
THE POTENTIAL WORTH OF THE MODELS USED FOR MEASURING THE
EFFECTIVENESS AND EXTENT OF STRUCTURE IN THE MATERIALS. THIS
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Some Effects of Unit Structure on Achievement and Transfer

Since about 1956, there has been a great deal of

emphasis on developing new courses for the schools in this

country. Much of the energy has been expended in developing

new courses in science for the secondary school. The develop-

ment of these courses is related to a movement to establish

new goals for science education in the secondary school.

Usually included as a goal is one which is in some way related

to what is called the structure of a science. There are

several assumptions underlying claims for the advantages of

a structured course over other courses, and these assumptions

deserve careful attention and consideration. On the basis

of these assumptions, it has been asserted that the new science

courses offer improvement over existing science courses by

teaching science in the best possible way - by basing the

presentation of science upon a structure of science. Yet

there is almost no experimental evidence available to sub-

stantiate any such assertion.

Advantages claimed for structured courses frequently

relate to motivation, achievement, retention, transfer, and

the efficiency with which knowledge can be organized for

learning. A pertinent statement of some assumptions upon

which claims commonly made must ultimately rest was made by

B. O. Smith in the "Introduction" to <u>Education</u> <u>and</u> <u>the</u>

<u>Structure</u> <u>of</u> <u>Knowledge</u> (Fifth Annual Phi Delta Kappa

Symposium on Educational Research.) The questions posed by

treating these as presumptions are self-evident. These

assumptions are:

1. That teaching will be more effective if it

incorporates the ways elements of knowledge are related

logically.

2. That what is learned will be retained longer if it is tied into a meaningful cognitive structure.

3. That what is learned will be more readily transferable if it is tied into a system of knowledge.

4. That the categories of the curriculum - what we ordinarily refer to in conventional terms as subjects - are somehow related to the categories of knowledge and that knowledge can be categorized in ways more conducive to learning than is ordinarily done.

Several studies dealing with the effects of changing the order in which learning materials are presented have been reported. Programmed learning materials were generally used as the medium for instruction, and criterion measures included such variables as achievement, learning rate, retention, and transfer. The ordered sequence has usually been a sequence of learning materials already available and the unordered sequence some random arrangement of these

materials. The results of this research have not provided

a clear picture of the effects of altering sequence on cri-

terion measures of learning. In most cases, the confusion

is very likely the result of a failure to clearly specify

what the ordered sequence of materials is to be and to de-

vise adequate tests to determine if the desired order exists

and if a random arrangement of the materials really gives a

different order. It will not make sense to consider the

effects of a sequence change on any criterion measure of

learning until it has first been established that a defined

sequence exists and that a change in the sequence has

actually been brought about by some alteration of the

materials comprising the instructional program.

In the study I am relating here, the first objective

was to produce a set of programmed materials which was

written to conform to a definition of order and an altered

version of these materials. The defined version was called

structured, and the definition was that which is encountered

frequently in discussions of structured science courses. A

structured unit was written using several concepts of measure-

ment in a way which would result in a development that

could be considered hierarchical. This hierarchical arrange-

ment was divided into four sections, and an achievement test

was written to be administered at the end of each section.

An unstructured version of the measurement unit was obtained

from this unit by taking a random sequence of these four

sections.

The second objective was two-part: First, to devise

a means of determining if the two versions effectively taught

the concepts of measurement. A second part was to devise a

means of testing the structured unit to see if it was indeed

structured and to compare it with the unstructured version

of the unit to see if there were detectable differences.

The work of Robert Gagné on learning hierarchies provided

the ideas for models used in making these two tests. Let me

digress a minute to give an abstract of the ideas I put

together to devise models for these tests. If a program is

hierarchical, the hierarchy can be traced to a base. At

the base there will be certain basic abilities with which

the learner must be equipped if he is to successfully com-

plete the learning hierarchy. If such a program were com-

pletely effective, all students would achieve all intended

elements in the program. In a program not completely

effective, however, some of the students would in effect

drop out at some point in the hierarchy. Those who drop

out would tend to be low on measures of basic abilities

relevant to the hierarchy, and the lower the basic ability,

the earlier the dropout would be expected to occur. This

dropout would be reflected in increasing correlations of

basic ability with achievement at successive points in the

hierarchy. The pattern of these correlation coefficients,

then, could be used to judge the effectiveness of a

structured program. A plot of correlation coefficients of

basic ability with achievement at points upward in the

hierarchy (plotted against some distance in the hierarchy)
would be expected to show near zero slope if the unit were
effective. A slight positive slope would indicate an
effective structured unit. A rapidly increasing set of
correlations, indicating a high dropout rate, would be
evidence of an ineffective unit.

Also, in a hierarchical program, achievement at a
given point depends upon both basic ability and achievement
at previous points. Basic ability would be important in
predicting achievement early in the hierarchy, but it would
become less important further in the hierarchy because
achievement comes to depend more and more on achievement
at the previous points and less and less on basic ability.
Consequently, a regression analysis could be used to judge the
extent to which a unit is hierarchical.

The third and final objective of the study was to in-
stitute an experiment which would provide the data (1)
for measuring the effectiveness of the two units, (2) for

deciding if they were structured and unstructured as claimed, and, these conditions being met, (3) for examining some effects of structure on measures of achievement and trans-fer.

About two hundred fourth, fifth, and sixth graders were selected from schools which were participating in a larger study. Arithmetic ability was considered basic to the hierarchy of measurement concepts, so a measure of basic arithmetic ability was obtained on these students. Using the two modes of program, the three grade levels, and three levels of basic arithmetic ability, a three factor, mixed-model analysis of variance design was used to test assumptions regarding the effects of mode of unit upon achievement and upon transfer. A multiple linear regression analysis was done to give correlations and partial regression weights for determing the effect-iveness of the units and for deciding the question of

structured and unstructured sequence.

Here is a brief summary of the results of the study:

1. No measurable difference in the effectiveness of the two units was found.

2. When grade and basic ability were not considered, mode of unit was found not to be a significant factor.

3. Grade level and ability level were found to be significant factors for both achievement and transfer. The student of high basic ability achieved higher than the student of low basic ability, and the older student seemed better able to transfer concepts.

4. There was a significant interaction between mode of program and basic ability when achievement was the criterion. The student of high basic ability achieved higher in the structured mode of program.

5. Both units were found to be effective.

6. The structured unit was found to be structured

and the random version was definitely different.

What is more promising than these results, however - at

this stage of investigation of the problem-is the potential

worth of the models used for measuring the effectiveness and

the extent of structure in the materials themselves. There

are not enough available plots of correlation coefficients

like those used in this study to allow one to judge what

pattern indicates the most effective unit. Nor has there

been enough done to decide what variable the coefficients

should be plotted against so that the patterns can be

mathematically described. On the basis of the results ex-

pected from the theory and those obtained in this study,

this method of measuring the effectiveness of materials

deserves further study. The questions relating to patterns

indicative of effective units, appropriate independent

variables for plots of correlation coefficients, and

mathematical descriptions of the plotted patterns are the

first in need of attention. More attention should also be

given to identification of relevant basic abilities for de-

fined structures - a prerequisite to the meaningful study

of effectiveness.

The success of the model used to determine the extent of

structure in the two units was also encouraging. There

was definitely a difference between the two units, and

since the units were intended to be different in structure,

this difference was attributed to structure. The patterns of

partial regression coefficients, while generally as expected

on the basis of the theory, are not as easily interpreted

as the correlations used for determining effectiveness.

The major weakness in this approach to identifying structure

is the assumption of an independent set of measures for the

linear regression model used. Any further attempt to use

this model should account for the dependence of achievement

at a given point upon achievement at preceeding points in

the program.

The results of this study suggest that attempts to examine the effects of sequence on learning measures should at this time be abandoned in favor of attempts to write programs which conform to a defined pattern and to develop the appropriate tools for testing these programs. Programs, self-instructional or otherwise, could be written to conform to a specified model. Techniques could then be developed for testing these programs to ascertain if they are in fact written as defined - the models in this study are an exemplar. Having batteries of such well-defined programs, one would then be equipped with the requisite tools for answering questions about the type of program and effects of changes in the program on such measures as achievement, retention, and transfer.

The models used here proved promising only for units. The ideas are easily extended, however, to include courses, disciplines, and even a structured K-12 curriculum. The possibilities for short range, intermediate range, and long range studies are immense. They are exciting. They are of

great importance from the standpoint of making the educational

enterprise more efficient and easier. This area of investi-

gation offers the thinking researcher a challenge and

promises him fruits for his labor.