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ABSTRACT

A study on the applicability of Snyder's 1968 prototheory of instructional efficiency to a complex problem-solving situation was made, using 120 sixth grade students of three geographically separated Pennsylvania schools in 1972. Four task groups, 30 subjects (Ss) each, were formed by randomly assigning four task arrangements to Ss in answering a genetics problem. The task varied in number of information items (hints) presented, either four or eight, and amount of "learning structure" used. The structure was made different by instructing Ss to read either in an arbitrary order or mandatory order. To reduce errors, a researcher-constructed machine was used to present the problem and hints and record students' responses and verbal expressions. Two revised efficiency formulas, respectively equivalent to Snyder's two original formulas, were introduced. Data about the four groups were analyzed to compare the revised and original formulas, and pooled results were used to study students' performance. The revised formula was proved equivalent to Snyder's expression for transaction mean needed by a teacher-student dyad to solve a problem. Both hint and learning structure had no effect on Ss performance. Extension of the present study was recommended. (CC)

A STUDY OF THE EFFECTS OF INFORMATION ITEMS ON SNYDER'S 1968 PROTOTHEORY OF INSTRUCTIONAL EFFICIENCY AS APPLIED TO A GENETICS PROBLEM-SOLVING SITUATION

by

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SYNOPSIS

This research investigated the applicability of Snyder's 1968 prototheory of instructional efficiency to a genetics problem-solving situation. Revised instructional efficiency formulas were compared to Snyder's 1968 formulas. Three sub-problems explored the effects of the number of information items on the instructional situation.

An important result of this research was the suggested equivalence of the formula, $\hat{s}_I = t_I/s_I$, to Snyder's formula, $\hat{s} = t/s = 1$. This finding opens new avenues of research and supports the notion that Snyder's 1968 prototheory may be applied to formal problem-solving situations.

The results of the subproblems indicated the variables, "learning structure" and the number of information items, had no effect on the performance of the one hundred twenty sixth-grade subjects.

The use of a researcher-constructed testing-recording machine aided this research by reducing teacher-researcher bias and error, and enabling the dissection of the dyad for analysis.

Introduction

The purpose of this research was to investigate the applicability of Snyder's 1968 prototheory of instructional efficiency to a complex problem-solving situation. Snyder's 1968 prototheory predicts optimum information exchange between a teacher and a student engaged in an instructional situation. The prediction is based on efficiency computed in terms of mean number of transactions and mean number of trials needed by the teacher-student dyad to perform a task. In order to apply Snyder's 1968 prototheory to a problem-solving situation, Snyder's ratios which define instructional efficiency were revised. The formulas proposed by Snyder were based on the number of teacher-learner transactions and the number of stages within a problem-solving situation. The revised ratios were intended to measure efficiency in terms of the number of information items included in an instructional situation.

In addition to the main problem, three subproblems were investigated. "Subproblem One" investigated the effects on instructional efficiency of the amount of information presented during the task. "Subproblem Two" investigated the effects of "learning structure" in presenting information. The effects of the amount of information and "learning structure" were tested by placing subjects in a problem-solving situation in which the variables of "information available" and "learning structure" (Gagne, 1965) were controlled. "Subproblem Three" investigated the validity of predicting the most efficient group. The efficiency value computed for the group predicted to be the most efficient was compared to the efficiencies computed for each of the three remaining task groups.

Procedures

Redefinition of Snyder's 1968 Ratios

According to Snyder's 1968 prototheory, an efficient problem-solving situation is one which requires the least number of exchanges of information between the tutor and learner and the least number of trials to solve the problem. The efficiency with which the learner and teacher exchange information is described by Snyder (1968) as $\acute{s} = t/s = 1$ where $\acute{s}$ is the mean number of transactions needed to solve each stage. The symbol "t" is the number of transactions. The symbol "s" is the number of stages needed to solve the problem.

Since the value of s is not always known, s takes on an arbitrary nature depending upon the value a teacher assigns to s, the number of stages needed to solve a problem. Also, the expression, $\acute{s} = t/s = 1$, does not describe the efficiency with which a student identifies the stages. Therefore, in order to obtain a more stable measure of efficiency, Snyder (1968) defines efficiency as $\hat{S} = S/T = 1$ where $\hat{S}$ is the mean number of trials permitted to achieve one successful response. The symbol "S" is the number of trials permitted. The symbol "T" is the number of successful trials.

The elimination of an arbitrary s may introduce stability. However, the statement $\hat{S} = S/T = 1$ says nothing about the efficiency of the messages exchanged. Snyder's statement implies the assumptions that all of the transactions are qualitatively equal and that a correct response can occur in one stage involving one transaction. This may be true in a simple stimulus-response situation, but the question arises as to whether this will hold in a more complex problem-solving situation.

On the assumption that complex problem-solving behavior may involve more than one stage and the solution to the problem may depend on the amount of information exchanged in a transaction between tutor and learner, the redefinition of $\hat{s} = t/s = 1$ and $\acute{S} = S/T = 1$ were effected.

The symbol "s" which was the number of stages, was redefined as s_I, which is the number of information items (hints) available in a problem. The symbol "t", which was the number of transactions, is redefined as t_I, which is the number of information items (hints) referred to by the subject. Snyder's formula for the mean number of transactions necessary to solve each stage, $\hat{s} = t/s = 1$, becomes $\acute{s}_I = t_I/s_I = 1$.

Snyder's formula for the mean number of trials needed to solve the problem, or the probability of a correct response occuring, was $\hat{S} = S/T = 1$. This formula was redefined to read $\hat{S}_I = S_I/T_I = 1$. The symbol "S_I" is the number of information items referred to by the student, not the number of trials permitted (as in Snyder's original expression). The symbol "T_I" is the number of trials necessary to achieve a correct solution by the student, not the number of successful trials (as in Snyder's original expression).

Description of the Task

All subjects were given the following genetics problem. The genetics problem was structured after the form used in L. H. Snyder (1946) and L. H. Snyder and David (1953). The problem was written as follows:

> In man, the occurence of normal skin color is due to a gene (N). The occurence of albinism, or lack of skin color, is due to a gene (n). A homozygous normal man marries a homozygous albino woman. What are the genotypes of these people?

All groups were asked to select the correct answer from the following two columns:

The Man	The Woman
N	N
n	n
NN	NN
Nn	Nn
nn	nn

The order of the letter symbols followed the convention of listing the dominant gene (capitalized) first. No restrictions were placed on any of the groups as to the number of trials they were permitted to make in order to select a correct answer.

This genetics problem, providing 10 answer choices, was selected in order to discourage random guessing on the part of the subjects. The 10 answer choices taken 2 at a time produced a probability of selecting a correct answer of only 1 in 45 trials by guessing; or, the probability of a correct answer occuring by chance is 0.02. It is assumed that the student would rather read the hints and go more directly to the answer than try all possible combinations of the 10 items.

The number of information items available to the short sequence group was determined by selecting the critical words in the problem. "Critical" words, words having "critical properties", were selected as "critical" on the bssis that if the subjects did not know their meaning they would not be able to arrive at a correct answer. These selected critical elements were used to construct four "critical information items" (hints). The information items in the four-hint set, or short set, for both the Mandatory Reading Four-Hints Group and the Free Selection Four-Hints Group (see below - "Description of Task Groups") were as follows:

1. Genotypes are the letter symbols that indicate which genes are present.
2. Genes are represented by letter symbols.

3. Genes occur in pairs.
4. "Homozygous" means all genes for a given characteristic are the same.

The choice of these four statements as being "critical" was supported by consultation with a high school biology teacher and a college professor, both having experience teaching genetics in their biology classes.

A second set of information items, the long set, was created by alternating the above items with four "noncritical" items. "Noncritical" items were formed by defining or making a short statement about words from the problem which were not considered necessary to the solution or were already defined in the problem. The four "noncritical" items were as follows:

1. "Normal" means the average appearance of a characteristic.
2. "Occurence" means an organism will have and display a physical characteristic.
3. "N" is a symbol representing a single gene for normal color. The symbol "n" represents a single gene for albinism.
4. Albinism is the lack of skin color. This produces a very white to pink appearance.

The four "noncritical" items along with the four "critical items" were read as hints by the Free Selection

Eight-Hints and Mandatory Reading Eight-Hints groups.

The choice of these four statements as being "non-critical" was also supported by consultation with the same high school teacher and college professor that judged the "critical" statements.

All information items were called "hints" during the experiment. The function of the hints was to enable the Ss to interact with the machine in order to obtain transactions between the student and "teacher".

Description of the Machine

The purpose of the machine was two-fold. In the pilot and main studies, the machine was used to uniformly present the problem, instructions and information items to all subjects in a given group. The use of the machine eliminated variation which may have occured due to a live teacher's presentation. The second purpose for using the machine was to record data. Recording data by the machine eliminated the possibility of inaccuracy due to visual observation, editing of behavior, and interpretation of students' responses on the part of the teacher-researcher. (In prior studies, the researcher functioned simultaneously as an observer and teacher. In this study, the researcher functioned only to present the machine operation instructions.)

The machine was designed to present the problem and hints upon demand. The problem and information items were taped beneath doors on the operations panel. When a student read the problem or any of the information items he had to open a door. When the door was opened, a stylus on the polygraph portion of the machine was activated.

To select an answer, the student had access to 10 answer choices. The answer choices were written on plugs. The answer choices remained visible at all times. When the students selected an answer they removed the plug from its original position on the panel and placed it in one of the two "Try Your Answer Position" receptacles. Both of these actions, removal and insertion, activated styli on the polygraph. The polygraph recorded the events on a moving paper.

The two "correct answer" plugs were constructed so that when they concurrently occupied both of the "Try Your Answer Position" receptacles they activated a "correct answer" stylus. The "correct answer" stylus was also connected to a "correct answer" light switch. The stylus simultaneously recorded the answer and signalled the subject that he achieved a correct answer.

Thus, in terms of recording, the machine was designed to record when the student began and when he finished, when and how many times he referred to the problem, which hints he read and the order in which he read them, which answers he attempted, how many times he tried a given choice, how many choices he made, and the relationship of the order and number of choices made to the reading of the problem and hints. Finally, the machine would automatically confirm a correct answer, thus signalling the subject that he had completed the task.

Selection of Subjects for the Study

Subjects for the study were obtained from three Pennsylvania Schools; the Upper Perkiomen School District (in Montgomery County, Pennsylvania), the Juniata Joint School District (in Juniata County, Pennsylvania), and the Daniel Boone Area School District (in Berks County, Pennsylvania). The three schools were chosen because of their accessibility. Also, their geographic separation increased the plausibility of generalizing beyond one school district.

Sixth grade was chosen because children at this age, 11 (Stone and Church, 1957), are in the beginning of the formal operations stage of cognitive development. Renner and Ragan (1968) state that the Piagetian formal operations stage occurs between the ages of 10 and 14. Piltz and Sund (1968) report the stage occurs between 11 and 15. Although it may not be possible to define a specific age for the onset of the formal operations stage of development, the choice of sixth grade places the students toward the beginning of the stage in both interpretations.

The selection of students in the early part of the formal operations stage enhanced the internal validity of the study by reducing the practice effect of the students having solved problems similar to the task in this study. Also, the subjects' familiarity with material similar to the experimental task was considered nil since the subject of biology for this and earlier grades in the participating schools did not include formal genetics problem-solving exerci   it was therefore assumed that a formal genetics problem was a suitable task for this study.

The choice of sixth grade was also considered reasonable because the students in the sixth grade should have developed the reading skills necessary for reading the problem and information items in the task. (Bloom, 1964).

Therefore, sixth grade students were considered to have the basic skills necessary for the performance of the task. They were also considered to have no prior experience with the genetics problem used in this study. Thus, they were suitable for this research.

The pilot study, consisting of thirty-three subjects, provided data to substantiate these assumptions.

One hundred twenty sixth-grade students were recruited for the main study. The students' teachers were instructed to select boys and girls in an alternate order. The students were sent one at a time to an isolated room where the task was presented by the machine.

In order to reduce selection bias, the teachers were not told the order of the task arrangements being presented, nor did the researcher influence the teachers' selection of specific individuals. Also, in order to reduce selection bias and insure randomness, the task arrangement was changed every five students. The four task arrangements were administered twice in each school. The order of the first set of four task changes in each school was determined by assigning a number from one to four to the four task arrangements. A table of random numbers (Rummel, 1964) was then used to order the first four task changes. The order of the second set of four task changes was a duplication of the first set. Therefore, randomness was achieved by randomly assigning the task to the subjects. Both Rummel (1964) and Siegel (1956) state that either the subjects or the treatments may be assigned to the task groups.

The above procedure resulted in the separation of the students into four groups consisting of 30 subjects each. Each task group contained equal numbers of students according to sex (five boys and five girls from each of the three schools). Equal numbers of students between schools were maintained as a precaution against the occurence of extraneous effects due to possible differences between schools. The total of 120 subjects and the arrangement of these subjects in task groups of 30 subjects each was determined prior to the study by a convention: Rummel (1964) states that 30 subjects per group is an adequate number of observations for experimental or control groups.

Description of Task Groups

One hundred twenty sixth-grade students (Ss) recruited for the study were divided into four groups of 30 Ss each. Two of the groups, groups FS8 and MR8, received long sets of information items (8 hints). Two of the groups, FS4 and MR4, received short sets of information items (4 hints). With two exceptions, the instructions for performing the task and operating the machine were the same for all groups. Groups FS8 and FS4 were given freedom to select information items in any order. These two groups were called the "Free Selection" groups (abbreviated FS8 and FS4 depending upon the number of hints available to the group). Groups MR8 and MR4 were instructed to read the information items in consecutive order. These two groups were called the "Mandatory Reading" groups (abbreviated MR4 and MR8 depending upon the number of hints available to the group). The elements, "Mandatory Reading" and "Free Selection", were considered to represent "learning structure" in this research. "Learning structure" was referred to as the amount of teacher-dictated problem-solving procedure. The mandatory reading groups were thought of as representing a pre-arrangement to the conditions for learning (Gagné, 1965).

To attempt to answer the questions posed in the subproblems, results from the task groups were pooled. Results from groups FS8 and MR8 were pooled as one group. Results from groups FS4 and MR4 were pooled as one group. These two sets of groups were then compared to test the effect of the amount of information available to the groups. As a test of the effects of "learning structure", results from groups FS8 and FS4 were pooled as one group. Groups MR8 and MR4 were pooled as one group. Results from these two sets of groups were compared to each other.

Findings of the Study

Testing of the subjects occured during the months of January through April of 1972. The genetics task was presented to the subjects by a researcher-constructed machine. Students' responses to the task were recorded by the machine. Verbal expressions of the students were tape-recorded.

No students were found to be sufficiently distracted by the machine sounds or school sounds to warrant the subjects' removal from the data pool. The novelty of the task situation and its electrical contrivances were not considered a cause of distractions which would influence the subjects' responses to elements of the task. Students' responses to questions posed by the researcher, at the conclusion of each test session, supported this assumption.

Determination of Task Group Equivalence

The design of the study controlled possible error due to extraneous variables: sex, age, intelligence level of the subjects. Control was achieved by randomly assigning the task to the subjects. Random assignment of the task was assumed to effect a uniform distribution of individual differences among task groups. As a check on the validity of this assumption, data were collected relative to the extraneous variables listed above. An equal distribution of boys and girls was maintained in all task groups. Analysis of variance computations indicated no significant differences among task groups in the variables age, achievement level, and intelligence level.

These findings under "Determination of Group Equivalence" support two assumptions underlying the design of the research: (1) random assignment of the task to the subjects resulted in random and uniform distribution of individuals' special attributes; and (2) potential error in treatment effects due to differences among schools was controlled by (a) random assignment of the task to the subjects, and (b) the maintaining of equal numbers of subjects from each school in task groups.

Analysis of the Task

Three variables were examined in order to support the initial assumption: the genetics problem as described would be suitable task for this research. The variables considered were: (1) numbers of students obtaining a correct response, (2) the time spent in performing the task, and (3) the frequency with which the subjects selected specific hints. The computed Chi-square statistic indicated no significant differences between task groups in number of subjects scored correct, the time needed to perform the task, and the frequency of hint selection.

One of the initial assumptions for the study was that the choice of the genetics problem would reduce random selection of answer choices by the subjects. If subjects selected random pairs of answers from the 10 answer choices (45 pairs) available, a probability of 1 correct answer in 45 trials or, $p = 0.022$ should result.

The assumption described above was tested by computing the ratio of the number of correct answers to the number of trials by the subjects who obtained a correct answer. The number of trials by these 90 subjects was 1,600. The ratio of correct answers to trials produced the probability of a correct answer occuring. The probability obtained was $p = 0.056$. Instead of achiev 1 correct answer in 45 trials as predicted for random selection, the subjects were obtaining 2.534 or almost 3 correct answers in 45 trials. These data support the use of the genetics problem with 45 pairs of answer choices possible, since the random occurence of correct answers on the part of the subjects was not obtained.

The objective of the hint selection analysis was to determine whether the subjects were selecting hints at random; or, whether the order of the hints, or the use of some strategy on the part of the subjects influenced hint selection.

The chi-square test indicating no significant differences among the number of times individual hints were selected suggested that the subjects in the task groups were not selecting hints at random. The order of the hints and/or some strategy employed by the subjects may have influenced the subjects' selection of individual hints.

As assumed prior to the study and reported by Bloom (1964), the findings also indicated the subjects had developed the reading skills necessary to perform the task. The findings showed the students were able to solve the problem, and, the occurence of a correct solution was due to the subjects' actively attempting to solve the problem.

The findings under "Analysis of the Task" seem to indicate the subjects had progressed to the Piagetian formal operations stage of development. However, even though the subjects were able to solve a complex problem with greater frequency than random occurence, it is questionable that they employed higher cognitive powers than trial and error reasoning. Students' verbal responses to the researcher's questions, after the conclusion of test sessions, indicated they employed the strategy of eliminating single-letter choices by trial and error. After the elimination of these single-letter choices, the subjects claimed to be able to associate the letters "N" and "n", as given in the problem, with the appropriate answer pair. If this was the case, the subjects were employing the strategy of trial and error coupled with a cognitive connection provided by the hint, "genes occur in pairs."

However, the data sheets do not substantiate the students' verbal description of the sequence of events leading to a correct solution. Data sheets from the recording portion of the machine indicate many students did eliminate the single-letter choices at the beginning of their test session, only to return to those choices at a later time or continue numerous trials and hint readings suggestive of a trial and error procedure. Since the data sheets preserve a record of the sequence of events but not the reason for the events, the data remain inconclusive. Research should be conducted to accurately determine the strategy employed by the students.

The findings that the subjects actively attempted to achieve a correct answer and were able to correctly solve the problem supported the decision to conduct the study in the sixth grade. Also, the choice of the genetics problem as a suitable task was supported.

Findings Related to the Main Problem

The investigation of Snyder's 1968 prototheory of instructional efficiency applied to a genetics problem-solving situation was conducted in two parts. "Part One of the Problem" was a test of the equivalence of the revised formula, $\hat{s}_I = t_I/s_I$, to Snyder's 1968 formula for the mean number of transactions needed by a teacher-student dyad to solve the stages of a problem; or, $\hat{s} = t/s = 1$. "Part Two of the Problem" was a test of the equivalence of the revised ratio, $\hat{S}_I = S_I/T_I$, to Snyder's 1968 formula for the mean number of trials needed by a teacher-student dyad to solve a problem; or, $\hat{S} = S/T = 1$. Each of the two parts to the problem were evaluated by using two tests: (1) a test employing data obtained from all subjects involved, and (2) a test employing data only from subjects who achieved a correct answer to the task problem.

In addition to the two parts to the problem described above, three subproblems were investigated: (1) the effect of the number of information items contained in the variations of the task, (2) the effect of the amount of "learning structure" contained within the problem-solving situation, and (3) the prediction that the most efficient task group would be the group exposed to the least amount of "learning structure," and, having access to the lowest number of information items.

Findings of Part One of the Problem -- Test One the Equivalence of $\hat{s}$ and $\hat{s}_I$. The values for $\hat{s}_I$ for each of the task groups were computed using data from all subjects involved. The computed values for $\hat{s}_I$ were compared to Snyder's (1968) prediction, $\hat{s} = 1$. The computed values for $\hat{s}_I$ were also used in an attempt to order the task groups from highest to lowest in efficiency. The obtained values for $\hat{s}_I$ were not found to be equal to Snyder's predicted value for $\hat{s}$, nor was it possible to order the task groups from highest to lowest in efficiency by using the computed values for $\hat{s}_I$. These data suggest that when data from all students are included in the computations of $\hat{s}_I$, $\hat{s}_I$ is not equivalent to Snyder's $\hat{s}$.

The early studies of Shaw (1932), Lorge and Solomon (1955), Restle (1962), and Hoppe (1962) attempted to describe group problem-solving behavior. These early studies retained data obtained by subjects who did not achieve correct answers to the task problems. The "incorrect" subjects were included in their studies since an individual scoring incorrectly on one trial or stage of the problem could contribute information to other persons in the group. Also, the person who was incorrect on one attempt could be correct on a later attempt. Thus, the interaction of all individuals contributed to the group's ability to solve a problem.

In the present study, subjects were not permitted to interact with one another. Subjects who could not obtain a correct answer contributed nothing to the group's ability to solve a problem. Therefore, a computation of $\hat{s}_I$ using data from all individuals including those scored "incorrect" neither supports nor refutes the early studies mentioned above. However, Snyder's prototheory indicated that only subjects reaching criterion were included. The suggestion that subjects who do not attain a correct answer contribute nothing to group success substantiates the decision to include only subjects who scored "correct" in the second test of the applicability of $\hat{s}_I$ to Snyder's $\hat{s}$.

Findings of Part One of the Problem - Test Two, the Equivalence of $\hat{s}$ and $\hat{s}_I$. The values for $\hat{s}_I$ for each of the task groups were computed using data from only those students who obtained a correct answer to the problem. The computed values for $\hat{s}_I$ were compared to Snyder's value for $\hat{s}$ as described in "Test One" above. It was found that the computed values for $\hat{s}_I$ do not equal "one" as predicted for Snyder's $\hat{s}$. However, the ordering of the task groups from highest to lowest in efficiency was the same as the order produced by ranking the groups according to the mean number of transactions. These data suggest that when data obtained only from students achieving a correct answer are employed in the computation of $\hat{s}_I$, $\hat{s}_I$ is equivalent to Snyder's $\hat{s}$.

The finding that the computed values for $\hat{s}_I$ in both tests under "Part One of the Problem" do not conform to

Snyder's (1968) prediction for $\hat{s}$; or, $\hat{s} = 1$, does not provide sufficient evidence to reject the equivalence of the two ratios. Snyder (1968) states the value, $\hat{s} = 1$, may be an ideal state, not attainable in actual practice. Therefore, $\hat{s}_I$ cannot be entirely judged by the criterion, $\hat{s} = 1$.

The ability of $\hat{s}_I$ to order the task groups from highest to lowest in efficiency was a more realistic test of the comparability of $\hat{s}_I$ and $\hat{s}$. The success of $\hat{s}_I$ in the second test under "Part One of the Problem" can be seen in the homologous nature of the elements composing $\hat{s}_I$ and $\hat{s}$. When applied to an instructional situation , the factors, t and s, of Snyder's expression, $\hat{s} = t/s = 1$, can be seen to be similar to the factors, t_I and s_I, of the revised ratio, $\hat{s}_I = t_I/s_I$. If the assumption is made that a stage (s) in a problem-solving situation consists of one "information item available" (s_I) then s and s_I are the same. Also, if a transaction (t) can be considered as one item of "information referred to" (t_I) then t and t_I are the same. Therefore, $\hat{s}$ and $\hat{s}_I$ may be considered equivalent.

Findings of Part Two of the Problem - Test One, the Equivalence of $\hat{S}$ and $\hat{S}_I$. For the first test under "Part Two of the Problem," the values for $\hat{S}_I$ were computed using data obtained from all subjects involved in the study. The computed values for $\hat{S}_I$ were compared to Snyder's $\hat{S}$; or, $\hat{S} = 1$. Also, an attempt was made to order the task groups from highest to lowest in efficiency by using the obtained values for $\hat{S}_I$. It was found that the computed values for $\hat{S}_I$ approached the value "one" but none were equal to "one". Also, the ordering of task groups from highest to lowest in efficiency was not possible by using the computed values for $\hat{S}_I$. These data suggest that when data obtained from all subjects are included in the computation of $\hat{S}_I$, $\hat{S}_I$ is not equivalent to Snyder's $\hat{S}$.

Findings of Part Two of the Problem - Test Two, the Equivalence of $\hat{S}$ and $\hat{S}_I$. The second test under "Part Two of the Problem" utilized data obtained only from those students who achieved a correct answer to the problem. The values for $\hat{S}_I$ were computed for all task groups and compared to the values for Snyder's $\hat{S}$; or, $\hat{S} = 1$, as described under "Part One". The values for $\hat{S}_I$ were found to be less than the value "one" as predicted for $\hat{S}$. Also, the ordering of the task groups from highest to lowest in efficiency was not possible by using the computed values for $\hat{S}_I$. These data suggest that $\hat{S}_I$ is not equivalent to Snyder's $\hat{S}$.

In both tests under "Part Two of the Problem", the findings that the computed value for $\hat{S}_I$ does not equal the value predicted for Snyder's $\hat{S}$; or, $\hat{S} = 1$, does not provide sufficient evidence to reject the equivalence of the two ratios. Snyder (1968) states the value "one" may be an ideal state not attainable in actual practice.

Therefore, $\hat{S}_I$ cannot be entirely judged by the criterion, $\hat{S} = 1$.

A more serious fault was the failure of $\hat{S}_I$ to enable the ordering of the task groups from the highest to lowest in efficiency. This error in $\hat{S}_I$ was attributed to the lack of homology between factors composing $\hat{S}_I$ and $\hat{S}$. When applied to an instructional situation, the factors, S and T, of Snyder's expression, $\hat{S} = S/T = 1$, are not homologous with the factors, S_I and T_I, in the revised expression, $\hat{S}_I = S_I/T_I$. The number of trials permitted, or S, could not be construed to have the same information value to the student as S_I, the number of information items referred to by the student. Neither could the value of T_I, the number of trials necessary to achieve a correct solution, be compared to T, the number of successful trials. In the present study, the value of T for any subject achieving a correct solution was "one" in all cases. The value of T_I was any value from one to as many trials as the subject could effect in 15 minutes. Therefore, the equivalence of $\hat{S}_I$ and $\hat{S}$ was rejected.

Findings of Subproblem Number One. Two statistical tests were conducted to determine the effects of the number of information items contained in a problem-solving situation.

For the first test under "Subproblem Number One," data obtained from students who achieved a correct answer were included. The number of transactions obtained by the eight-hint and four-hint task groups were compared by the chi-square statistic to an equal distribution of transactions between task groups.

For the second test under "Subproblem Number One," only data from subjects scored "correct" were included. The t-test for a difference between means was employed in the comparison of the number of transactions obtained by the two sets of task groups, the eight-hint and four-hint groups.

The computed values for chi-square and t indicated no significant difference existed between the number of transactions obtained by the two sets of task groups. Therefore, the number of information items available was found to have no effect on the number of transactions obtained by the two sets of task groups.

Walker and Bourne (1961), Dickerson (1970), and Clark (1971) indicate that an increase in the number of critical properties presented to the student facilitates concept attainment. The findings of these studies were supported by the findings of the present study. There were no differences in the number of transactions among task groups; no differences in the amount of time used in performing the task; and, no differences in the number of subjects obtaining a correct response to the problem. These findings may be the result of the effect of the number of "critical" information items available to the to the subjects. All task groups had access to the same four "critical" hints. Two of the groups had access to an additional four "noncritical" hints. Therefore, since performance was the same and since task groups had access to different numbers of hints yet had access to the same set of critical hints, the total number of hints available to the task groups had no effect on the performance of the subjects.

Findings of Subproblem Number Two. Two tests were conducted to determine the effect of the amount of "learning structure" contained in a problem-solving situation.

For the first test under "Subproblem Number Two," subjects who achieved a correct answer and subjects who did not achieve a correct answer were included. The number of transactions obtained by the mandatory reading task groups (MR8 and MR4) and the number of transactions obtained by the free selection task groups (FS8 and FS4) were compared to an equal distribution of transactions between task groups by the chi-square statistic.

For the second test under "Subproblem Number Two," only data obtained from subjects who obtained a correct answer were employed in the t-test for differences among mean number of transactions obtained by the free selection groups and the mandatory reading groups.

The computed chi-square and t-values indicated no significant differences between the means of the two sets of task groups. Therefore, the number of transactions obtained by the free selection task groups and the mandatory reading task groups was not affected by the amount of "learning structure" employed.

Lutz (1970) found the task group having the least amount of imposed structure, "learning structure," performed better than groups having greater amounts of "learning structure". Clark (1971) indicated that a focusing of the subject, or an increase in "learning structure," facilitates learning. The findings of this study supported neither position. No differences were found among groups subjected to variations in "learning structure". Group performance was the same in terms of number of transactions, number of students obtaining the correct answer, and amount of time needed to perform the task.

Findings of Subproblem Number Three. The prediction that the most efficient task group would be the task group exposed to the least amount of "learning structure," and, the group having access to the lowest number of information items was tested. Task group FS4 was predicted to be the most efficient under the above assumptions. Two comparisons of the task groups were effected: the task groups were compared to one another by their computed values for $\hat{S}_I$; and, compared to one another by their respective mean number of transactions. Neither comparison substantiated the prediction. Task group FS4 was not shown to be the most efficient group. This finding was supported by the findings of subproblems One and Two; both subproblems providing evidence to show no significant difference in the number of transactions obtained by the task groups.

Summary and Implications of the Research

The main problem studied in this research was to determine whether Snyder's 1968 description of instructional efficiency was applicable to a genetics problem-solving task. The approach of the investigation was to determine whether revised ratios, $\hat{s}_I$ and $\hat{S}_I$ for Snyder's 1968 measures of instructional efficiency, $\hat{s}$ and $\hat{S}$, were equivalent. The findings partially supported the applicability of Snyder's 1968 prototheory to a genetics problem-solving situation and partially supported the use of the revised ratios. Support for the prototheory was found in (1) the use of the transaction as a unit of measure for describing task group performance, and, (2) in the suggested equivalence of $\hat{s}_I$ to Snyder's $\hat{s}$.

Few generalizations were possible as a result of this research. Results of the subproblems indicated no significant differences among task groups compared among the variables; the number of information items available, and amount of "learning structure" contained within an instructional situation. The implications of the subproblems are that the number of information items was not as important to the optimal performance of the student as was the quality of the information. Also, the "learning structure" imposed by the teacher was not as important as the strategy employed by the student. The findings of this study indicate that the number of information items and the instructional strategy, "learning structure," imposed by the "teacher" had no effect on the performance of the subjects. The subjects seemed to adopt "their own" strategy and find "their own" set of "critical" information items.

The most important result of this research was the suggested equivalence of the ratio, $\hat{s}_I = t_I/s_I$, as a measure of instructional efficiency, to Snyder's 1968 ratio, $\hat{s} = t/s$. This finding supports the notion that Snyder's 1968 prototheory of instructional efficiency may be applied to formal problem-solving situations. The equivalence of $\hat{s}$ and $\hat{s}_I$ opens new avenues of research. If the equivalence of $\hat{s}$ and $\hat{s}_I$ are substantiated by future research, the use of $\hat{s}_I$ as a measure of instructional efficiency will enable the study of the applicability of Snyder's prototheory to instructional situations where the computation of Snyder's $\hat{s}$ is not possible. Thus the most important result of this research was to increase the area in which the investigation of Snyder's 1968 prototheory may be conducted. The expansion of the variety of situations in which Snyder's

1968 prototheory may be tested will permit more thorough analysis of the principles of the prototheory.

An important result of this study not reported as a subdivision of the main problem was the successful use of the researcher-constructed machine. The successful use of the machine aided this research by reducing the number of uncontrolled independent variables. The study of student responses was free from error due to inconsistency or personal bias on the part of a live teacher-researcher. Snyder's 1968 prototheory and subsequent studies were structured as attempts to describe the process of information exchange between the teacher and the student working in a dyadic situation. Snyder (1968) attempted to refine the techniques of the earlier studies of Shaw (1932), Lorge and Solomon (1955), and Hoppe (1962) by reducing group size to the dyad. Reduction in group size can be seen as an attempt to dissect the group in order to better understand the nature of its parts - the teacher and the student. The use of a machine as described in this study in place of the teacher or student enables a finer dissection of the group, and a selective and uniform examination of the groups' constituents. Thus, the use of a machine in place of the student or teacher in future research expands the researcher's capability to refine the selectivity and reliability of the data collection process.

Recommendations for Future Research

The following recommendations are suggested to provide additional tests of Snyder's 1968 prototheory, extensions of this study, and investigations of the nature of information exchange between teachers and students.

1. Additional studies should be undertaken to increase the generalizability of Snyder's 1968 prototheory to a greater variety of problems involving similar and more rigorous cognitive levels.

2. Additional studies should be undertaken to increase generalizability of Snyder's 1968 prototheory to subjects in a greater number of schools, and to subjects in a wide range of age and educational levels.

3. Future research should be conducted to determine the validity of $\hat{s}$ and $\hat{s}_I$ as measures of instructional efficiency.

4. Replication studies should be performed to determine the reliability of the equivalence of $\hat{s}$ and $\hat{s}_I$ as suggested in this study.

5. Studies should be divised to identify the imprrtance of the constituent elements of a problem-solving situation. The importance of the information items to the solution of the problem should be studied. Also, the students' interpretation of the importance of the information items should be studied.

6. Future research should be directed at identify-

ing the strategies employed by students working at a variety of different problems and a variety of age and ability levels.

7. Further definition of the transaction as a unit of measure of instructional efficiency should be considered for future research.

8. The machine should be used in place of the student in research to determine the nature of the teacher's performance in a dyadic situation.

9. The use of the machine, as described in this study, in place of the student or teacher, should be tested against situations in which efficiency is measured for a dyad of live participants.

10. The description and continued testing of the amounts of "learning structure" should be more thoroughly studied.

11. Studies directed at the determination of the type and amount of information contained within a transaction should be conducted.

12. Optimization studies should be devised to determine the effect of the number of information items on a student's ability to solve a problem.

13. Studies should be devised to clarify how much information is contained in an information item.

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