AN EVALUATION OF METHODS OF TEACHING FOR DISCOVERY

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The author, in a previous study, analyzed and described learning by discovery (Stokes, 1966). One facet of the analysis was the identification and classification of the various instructional methods which have been used to teach for discovery. The purpose of this study is to evaluate the effectiveness of these methods of teaching for discovery.

Six advantages claimed for learning by discovery were identified in the previous report. Since these advantages were reputed to result from learning by discovery, they may be used as criteria to evaluate the effectiveness of instructional methods used to teach for discovery. These advantages will be used as sources for the derivation of the evaluation criteria used in this study. The advantages claimed for discovery learning were as follows:

1. It promotes meaningful learning.
2. It strengthens and extends intellectual potency and cognitive skills.
3. It is intrinsically motivating.
4. It aids transfer of learning.
5. It teaches the heuristics of discovery.
6. It aids memory processes.

Data for the evaluation were obtained by a review of the current literature on discovery learning. Several characteristics of the studies reviewed limit the nature of the evaluation presented in this chapter. First, since many of these studies did not define their methods of teaching for discovery adequately enough for further classification, it was not possible to make an intensive study of the relative effectiveness of the three specific methods of teaching for discovery. However, a limited evaluation of the effectiveness of the three methods is presented, based upon data from the five studies which contained adequate definitions of the terms.

Second, most of the studies compared methods of teaching for discovery with other methods of instruction. These other nondiscovery methods may be distinguished from the methods of teaching for discovery by the fact that the nondiscovery methods provide the learner with the generalization or answer relevant to the problem situation. The methods of teaching for discovery, on the other hand, require

that the learner "discover" the answer or generalization for himself. Numerous terms are used for nondiscovery methods. Among the most frequently used ones are rote learning, direct-detailed methods, directed instructions, and directed learning. The descriptions of the nondiscovery methods of instruction were also not adequate enough to permit further classification according to various types of nondiscovery methods. Therefore, data from these studies can be used only to compare the effectiveness of general rather than specific methods of instruction. Specifically the effectiveness of general methods of teaching for discovery are compared to general methods of nondiscovery instruction. Only this broad two-fold comparison is possible from the data available.

From the above it can be seen that the evaluation of the methods of teaching will consist of two parts. The first part of the evaluation will be based upon a comparison of the effectiveness of method of teaching for discovery and methods of teaching which do not involve discovery. The relative effectiveness of the two diverse methods of instruction were evaluated in terms of the six criteria derived from the advantages claimed for discovery learning.

The second part of the evaluation will consist of applying the same six criteria used in the first part of the evaluation to three basic methods of instruction for discovery. These basic methods are (1) the autonomous method, (2) the guided method, and (3) the directed method. In addition to the six criteria used above, a seventh criterion, the efficiency of the three methods as determined by the length of time and number of steps required to make the discovery, will be used. This criterion was not used in the first part of the evaluation because the proponents of discovery learning concede that their methods of instruction require more time and a greater number of steps than nondiscovery methods of instruction.

Evaluation of the Relative Effectiveness of Methods of Instruction for Discovery and Methods of Instruction Which Do Not Utilize Discovery

In describing the instructional methods used in the studies, it would be more convenient to use shorter terms than the methods of instruction for discovery and the methods of instruction which do not utilize discovery to refer to the two basic forms of instruction being evaluated. Therefore, the methods of instruction for discovery shall be referred to as discovery methods. The methods of instruction

which do not utilize discovery shall be referred to as the nondiscovery methods. However, when a descriptive term, such as rote learning, is used as the nondiscovery method in a study, this term will be placed in parentheses immediately after nondiscovery method. This is done to give the reader a clearer idea about the nature of the comparison being made.

Criterion I -- Meaningful Learning

The extent to which learning is meaningful can only be inferred, never directly determined. The studies dealing with this criterion have used three means of inferring the meaningfulness of learning. First, they have used various forms of achievement tests for this purpose. Second, they have observed the learner's behavior in an attempt to find clues of understanding and meaning. Third, they have based their estimates of meaningful learning on the learner's ability to verbalize about what he has learned. Of these three methods of inferring meaning the use of achievement tests is by far the most common.

In the review of the literature eleven studies were located which attempted to determine the influence of discovery on meaningful learning. Brief descriptions and the conclusions of these studies are reported below.

In a study designed to measure the effects of nondiscovery (rote) and discovery methods on concept attainment, 70 high school or college subjects were administered the Hanfmann-Kasain or Vigotsky Block Test (Carpenter, 1956). The nondiscovery group memorized the generalization appropriate to the task. The discovery group had to discover the same generalization through observation and manipulation of the materials and the testing of hunches. The results of the study indicated that the discovery method leads to more thorough understanding of the concepts than the nondiscovery method.

Charen (1963) compared the achievement of 268 students using both discovery methods (open-ended laboratory experiments) and nondiscovery methods (the traditional laboratory exercises found in a standard chemistry laboratory manual). While using the open-ended experiments the students were expected to formulate their own conclusions. The nondiscovery methods, on the other hand, used the laboratory exercises to verify generalizations which the students had already been taught. The results of the study revealed that the students showed significantly better knowledge of chemical facts and principles when using discovery methods. Tests of critical thinking in chemistry revealed no significant differences between the two methods.

In a study of the influence of five different methods of instruction on learning, subjects were asked to identify which of five words did not belong with the other four. The five methods of instruction varied according to the amount of information given to the subjects. Among the results of the study two are related to meaningful learning:

> It makes for better learning if the learner proceeds by a method of active participation involving self-discovery rather than by a method of passive participation involving only recognition or identification of information previously provided to him.
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> . . . . . .
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> The learner obtains as many or more facts, and discovers more correct reasons for them, by a process of self-discovery than by a process of authoritative identification (Stacey, 1949).

Huxtable (1938) made a study to compare the achievement of 104 eighth- and ninth-grade students in three areas of English: vocabulary, reading comprehension and interpretation, and creative writing. One group of students, using discovery methods, guided their own work. The other group, using nondiscovery methods, were provided with detailed instructions for their work. The results of the study indicated that there were no significant differences in the achievement of the two groups.

Much the same results were reported by Grote in a study comparing nondiscovery (direct-detailed) and discovery methods of teaching physics. The results indicated that "the group instructed by the direct-detailed method was superior to the directed discovery group as measured by the first initial learning test. However, there was no difference between these groups when measured for initial learning following the second lesson . . . ." (Grote, 1960).

In a related study Moss (1961) compared the effectiveness of nondiscovery (direct-detailed) and directed discovery methods for teaching letterpress imposition. He concluded that there were no significant differences in the learning which occurred by either method.

Another study, closely related to the two studies above, compared the influence of the same two methods on the learning of orthographic projection principles and skills. The results lead the author to conclude that "the direct-detailed and the directed discovery methods are equally effective in regard to the initial learning of orthographic projection principles and skills" (Rowlett, 1960).

Research on the Inquiry Training Program has also failed to show that meaningful learning is increased by this type of discovery method. The results of an intensive study of the Program indicate that there is no significant differences between the achievement of the experimental (discovery method) group and the control (nondiscovery method) group. Although there were some differences in favor of the experimental group in regard to the mastery of principles, these differences were also not significant (Suchman, 1962).

A comparative study of the effects of discovery methods and nondiscovery methods (direct instructions) on learning was reported by Ray (1961). The subjects were ninth-grade boys enrolled in shop classes. The task consisted of learning to use the micrometer. Basing his conclusions on test results, Ray reported that there was no statistically significant differences between the initial learning of the discovery and direct instruction groups.

Kersh (1958) attempted to deal directly with the influence of discovery methods on meaningful learning. Defining meaningful learning as the increase in a learner's cognitive understanding or organization, Kersh's experimental design involved three different methods of instruction: a guided discovery method, a directed discovery method, and a nondiscovery method. Subjects using each of the three methods were confronted with the same task, the learning of two rules of addition. Based upon an analysis of test data, Kersh concluded "that the superiority of the discovery procedure of learning over procedures of learning with external direction is not adequately explained in terms of 'meaningful learning.'"

A later study by Kersh used basically the same experimental design. Although the major purpose of the study was to examine the influence of discovery methods on motivation, some highly significant results are reported on the relationship between discovery methods and meaningful learning. In stating his conclusions Kersh observed:

> The data from this present experiment do not support the generalization that learning by a process which involves discovery is necessarily superior to learning by more highly directed processes. Indeed, these data suggest that under certain conditions of learning, highly formalized "lecture-drill" techniques, ordinarily considered sterile and meaningless, produce better results than techniques which attempt to develop "understanding."

. . . . . .

> If it is important only that the task be understood (as is most often the case, presumably), the essential relationships may be learned most economically when taught by another person or teach-program, not by process or self-discovery (Kersh, 1962).

A summary of the results of these eleven studies shows that three studies indicated that learning by discovery methods does promote meaningful learning. Six studies, however, found that discovery methods offered no advantage over nondiscovery methods. And two studies indicated that meaningful learning is not attributable to the use of discovery methods. These conflicting results lead to the general conclusion that the question of whether or not nondiscovery methods is unsettled. The evidence is inconclusive so no decision may be reached.

Criterion 2 -- Intellectual Potency and Cognitive Skills

The survey of the professional literature in education failed to uncover a single experimental study of the effects of discovery methods on the development of intellectual and cognitive skills. Therefore, no evidence is available for an evaluation by this criterion.

Criterion 3 -- Intrinsic Motivation

Research studies on the influence of discovery methods on motivation are few in number. The review of the literature located only three studies dealing with this topic.

In a study conducted primarily to determine the influence of discovery methods on meaningful learning, Kersh also uncovered some findings pertinent to motivation. He found that on retests of achievement the subjects instructed by discovery methods showed substantial increases. Investigations into the reasons for these increases revealed that these subjects had continued to work after the learning periods were over. Evidence of this fact was found in written comments made by the subjects. Several subjects told the author that they had continued to work on the discovery problems, and one subject even tried out some of the problems on his friends. In explaining the results of this study the author reported "that when the learner is forced to rely on his own cognitive capacities, it is more likely that he will become motivated to continue the learning process or to continue practicing the task after the learning period" (Kersh, 1958). Kersh also concluded that this increase in motivation was responsible for the superiority in achievement of discovery methods over nondiscovery methods.

In another study closely related to the one just reported Kersh limited his investigation directly to the influence of discovery methods on motivation. Three groups of 30 subjects were taught two rules of arithmetic. One group used discovery methods while the other two groups used nondiscovery methods (directed learning and rote learning). All subjects were given tests of recall and transfer at the end of three days, two weeks, and six weeks. The subjects also completed a questionnaire at each of these three times. The results of the recall and transfer tests revealed that the discovery group did as well as the rote learning group and did better than the directed learning group. The questionnaire indicated that the discovery group continued to practice the learning tasks after the formal learning period had ended. This led Kersh to conclude that "learning by self-discovery is superior to learning with external direction only insofar as it increases student motivation to pursue the learning task. If sufficiently motivated, the student may then continue the learning process autonomously beyond the formal period of learning." (Kersh, 1962). Thus, this confirms Kersh's earlier conclusion.

The third study, Suchman's research on his Inquiry Training Program, found that the discovery method had a definite influence on students' motivation:

> Our main conclusion from the test results and from our experience with Inquiry Training in many classrooms is that the technique in its present form has a marked effect on the motivation, autonomy and question-asking fluency of children. They clearly enjoy having the freedom and the power to gather their own data in their quest for assimilation (Suchman, 1962).

Although the evidence on the motivating effects of discovery methods is limited to three experimental studies, all three of the studies indicate that discovery methods are intrinsically motivating.

Criterion 4 -- Transfer of Learning

The survey of the literature uncovered eleven studies of the influence of discovery methods on transfer of learning. By transfer of learning is meant the ability of the learner to utilize information gained in an earlier situation in a related, but not identical, later situation. Comparative tests of transfer resulting from discovery and nondiscovery methods are reviewed below.

In 1947 Hendrix conducted a study of the influence of different teaching methods on transfer after a lapse of

about two weeks. One of the methods studied, the unverbal awareness procedure, has been identified as a discovery method. The results of Hendrix's investigation indicated that "in every case the highest transfer effects were achieved in the group taught by the unverbalized awareness (discovery) procedure . . . and the lowest transfer effects came from the group taught by . . . the method in which the generalization was stated first, then illustrated, then applied to new problems (nondiscovery method) (Hendrix, 1947).

Kersh's study of the influence of discovery methods on meaning revealed some significant information about the influence of these methods on transfer. Transfer was measured four weeks after the conclusion of instruction by a retest designed especially to measure the subjects' ability to apply what they had studied to a similar problem situation. Each subject was required to make a self-report of the processes he used in attempting to solve his problems. A comparison of the tests score and the self-reports led Kersh to conclude that discovery methods increase a learner's motivation, and this, in turn, results in learning that "is more effectively transferred than when the learner is not so motivated" (Kersh, 1958). Thus, indirectly discovery methods improve transfer.

A study conducted by Haslerud and Meyers (1958) investigated the effects of given and individually derived (discovered) principles on transfer. Each of 76 college students used both methods. Transfer was measured a week after all instruction ceased by means of tests on problems similar to the ones studied. The authors reported that the "results give strong support to the postulate . . . that independently derived (discovered) principles are more transferable than those given."

Rowlett's study (1960) of nondiscovery (direct-detailed) and directed discovery methods included the investigation of the effectiveness of these two methods for transfer. Subjects for the study were 168 ninth-grade students. Half of them used nondiscovery methods and the remaining half used discovery methods. Based upon a comparison of transfer test scores, the author concluded that the discovery method more effectively promotes transfer after a lapse of six weeks than does the nondiscovery method.

Ray (1961) conducted a similar study of the effects of directed-discovery and nondiscovery (directed-instruction) methods on the transfer of knowledge of facts and principles of and ability to use the micrometer. The subjects were 1,700 ninth-grade boys. Transfer was measured by a teacher-made test and by observation of the subject's performance six weeks after all instruction was concluded. The

results indicated that the directed discovery method was significantly superior to the nondiscovery method in promoting transfer.

Kersh (1962) made a study of the transfer value of teaching two rules of arithmetic by one discovery and two nondiscovery methods (rote learning and directed learning). Subjects for the study were 90 high school geometry students. Transfer was measured by a test on problems similar to those used during the learning period. Each subject also completed a questionnaire designed to determine the learning processes used by the subject. The test was administered three days, two weeks, and six weeks after all instruction was completed. The results indicated that the rote learning group achieved the best transfer. The discovery group, however, showed better transfer than the directed learning group. Kersh reports that the questionnaire indicated that the discovery group practiced its problems after the conclusion of the learning period. This led Kersh to conclude that this increased motivation of the discovery group explains its superiority over the directed learning group.

Grote (1960) compared the effectiveness of nondiscovery (direct-detailed) and directed discovery methods in promoting the transfer of selected principles of physics. A transfer test was developed by the author and administered to the subjects one and six weeks following instruction. The results indicated that both methods were equally effective in developing transfer.

Moss (1961) compared the same two methods for effectiveness of transfer of letterpress imposition. Subjects using both methods were given forty-seven minutes of instruction. Transfer was measured by tests developed by the author. The author concluded that both methods were equally effective in promoting transfer.

Craig (1953) made a study of the influence of four methods of instruction on learning and transfer. Only three of these methods may be classified as discovery methods. Since the fourth method of instruction gave complete information about the generalization, it is classified as a nondiscovery method. Subjects taught by this method had only to apply the generalization to the test situation. Basing his conclusions of the analysis of transfer test scores for the four methods of instruction, Craig found that the nondiscovery method provided the highest level of transfer. Subjects given all relevant information showed better transfer of

learning than did subjects who had to discover all or part of the relevant information. In summarizing his evidence Craig stated that "the most reasonable interpretation of all the evidence available appears to be that subjects of all ages use and benefit from all the help given them in their search for bases determining correct responses" (Craig, 1953).

Hendrickson and Schroeder (1941) conducted an experiment to determine the influence of knowledge of generalization on transfer. One group of subjects used discovery methods to obtain the generalization while the other group was given the generalization. Both groups were considered to have understood the generalization only after they used it successfully in three consecutive problem situations. The results revealed that the nondiscovery methods promoted better transfer of learning.

A study by Kittell (1957) was designed to test the relative effectiveness of three methods of instruction during learning on the transfer of principles. The group taught by discovery methods was told only that a principle was involved in their task. The other two groups were given the principle. The results of the study indicate "that furnishing learners with information in the form of underlying principles promotes transfer . . . of learned principles and may provide the background enabling future discovery of new principles" (Kittell, 1957).

Of the eleven studies of transfer six reported findings in favor of discovery methods. Two studies found no difference between the transfer value of discovery methods and nondiscovery methods. Finally, three studies indicated that discovery methods were inferior to nondiscovery methods in promoting transfer of learning. Since the evidence is conflicting, no conclusion can be made in relation to this criterion.

Criterion 5 -- Heuristics of Discovery

Only two studies of the effects of learning by discovery on the development of heuristics were located. A study conducted by Ashton compared the problem solving abilities of two groups of students. One group used a discovery method designed to make the students self-directive. The other group used the "textbook method," a procedure in which solutions to problems are first demonstrated by the teacher and then the students are assigned similar problems (a nondiscovery method). The results of the study revealed that the discovery method produced greater improvement in problem solving than the nondiscovery method. Ashton concluded that "students benefit by being allowed to find their own solutions

if they are helped sufficiently to give them direction and to keep them working, but not so much as to kill initiative (Ashton, 1962).

The second study was conducted by Suchman to evaluate his Inquiry Training Program which is specifically designed to teach the heuristics of discovery. In summarizing the results of the Inquiry Training Program Suchman states that he was unable to "arrive at many firm conclusions either in relation to a theory of inquiry or the practical effects of Inquiry Training in a broad or long range sense (Suchman, 1962). However, Suchman does report that the questions asked by children in the Program improved considerably.

The first study found that discovery methods teach the heuristics of discovery better than nondiscovery methods. The second study, however, failed to show that use of a discovery method taught the heuristics of discovery. These results, coupled with the fact that only two studies were located, indicate that no conclusion can be made in regard to this criterion.

Criterion 6 -- Memory Processes

The effectiveness of discovery methods in improving memory process is stated in terms of their influence on retention. The survey of the literature produced eight studies which attempted to evaluate the effects of discovery methods on retention.

Carpenter's (1956) study of the effects of two learning methods revealed that the functional or discovery method promoted greater retention than the nondiscovery (rote) method.

A study by Rowlett (1960) comparing nondiscovery (direct-detailed) and directed discovery methods of teaching revealed that the discovery method was superior to the other method in increasing retention of principles and skills.

In a study of the effects of independent discovery methods and nondiscovery methods, Kersh found that the independent discovery methods resulted in superior retention. An analysis of self-reports made by the subjects of their learning processes and methods indicated that those subjects using discovery methods were motivated to continue to practice their work after the formal learning period was completed. This led Kersh to conclude that "the learning be-

comes more permanent...than when the learner is not so motivated (Kersh, 1958).

A later study of the effects of discovery methods on motivation was made by the same author. The results confirmed those reported above: the superiority of discovery methods results from increased motivation. The end result is that "the learner may then..remember what he has learned longer..." (Kersh, 1962).

Ray concluded a study comparing discovery methods and nondiscovery (direct instruction) methods. He reported that "the directed discovery approach to teaching is superior to direct and detailed instruction with respect to retention of material..." (Ray, 1961).

A study by Grote (1960) failed to find any difference in retention resulting from learning by directed discovery and nondiscovery (direct-detailed) methods.

A study by Moss (1961) of the same two methods also failed to find any significant differences in retention.

In a study comparing the effects of three methods of instruction on the retention and transfer of principles, Kittell reported that "after periods of two and four weeks subsequent to training, the group receiving an intermediate amount of direction, a nondiscovery method, retained a greater proportion of learned principles than the other two groups, using discovery methods (Kittell, 1957).

Five of the eight studies reported that discovery methods aid retention. Two of the studies found no difference between discovery and nondiscovery methods in promoting retention. One study concluded that nondiscovery methods were superior to discovery methods in aiding retention. Although the results of these studies tend to show that discovery aids retention, they do not provide conclusive evidence.

Summary of the Relative Effectiveness of Discovery Methods and Nondiscovery Methods of Instruction

Criterion 1--Meaningful Learning. Eleven sources of data were found for this criterion. Since the data conflict, there was not conclusive evidence that one method fostered meaningful learning better than the other.

Criterion 2--Intellectual Potency and Cognitive Skills. No data were available for an evaluation by this criterion.

Criterion 3--Intrinsic Motivation. Three sources of data were found for this criterion. The data indicated that discovery methods have better intrinsic motivation than non-discovery methods.

Criterion 4--Transfer of Learning. Eleven sources of data were located for this criterion. Because the data are conflicting, no conclusion could be reached as to which method better promoted transfer of learning.

Criterion 5--Heuristics of Discovery. Only two sources of data were found for this criterion. Since the data were ambiguous, no conclusion about the superiority of either method could be reached.

Criterion 6--Improvement of Memory Processes. Only data relevant to retention were found. Eight sources of these data were located. Although there was some conflict among the data, the evidence tended to favor discovery methods over nondiscovery methods.

Of the six criteria used to evaluate the relative effectiveness of the discovery and nondiscovery methods of instruction, no definite statement of the superiority of either of these methods can be made. However, there was some indication that discovery methods may be slightly more effective than nondiscovery methods in regard to two of the criteria. These criteria are the extent of intrinsic motivation and the promotion of memory processes.

Evaluation of the Relative Effectiveness of Three Methods of Instruction for Discovery

Five studies of the effectiveness of various methods of instruction for discovery were located by the survey of the literature on discovery learning. These methods of instruction differ from each other in the amount of direction provided for the learner as he attempts to discover. Each of the five studies used different terms to identify their methods of instruction for discovery. In order to compare the results of the five studies it is necessary to group similar methods of instruction together. This has been accomplished by organizing the methods according to three basic methods of instruction. Table 1 shows the classification of these methods. The sources of the methods are also indicated in Table 1.

In order to facilitate discussion, the various instructional methods used in the five studies will be referred to as autonomous, guided, or directed rather than by the terms used in the studies themselves. Thus, Bruner's Random method will be called the autonomous method, as will Stacey's Method A.

Table 1

Classification of Methods of Instruction for Discovery Used in Five Studies

Study	Basic methods of instruction Discovery		
	Autonomous	Guided	Directed
Bruner[a]	Random	Ordered	
Craig[b]	Nonguidance	Guidance G	Guidance GX
Kersh[c]		No-help	Directed-reference
Sechrest[d]	Condition I	Conditions II and III	
Stacey[e]	Method A	Method B	

[a]Bruner, 1956

[b]Craig, 1953

[c]Kersh, 1958

[d]Sechrest and Wallace, 1962.

[e]Stacey, 1949

The three basic methods of instruction for discovery will be evaluated by seven criteria. The same six as used above in the evaluation of discovery methods and nondiscovery methods will be retained. The seventh criterion is the length of time and number of steps required for discovery. This criterion was not used in the above evaluation because the proponents of discovery methods conceded that their methods required more time and steps than nondiscovery methods. Because of the importance of time and the degree of complication required by an instructional method, it is important to determine the relative efficiency of the three basic discovery methods in these respects. For this reason the seventh criterion was adopted.

Criterion 1 -- Meaningful Learning

Stacey (1949) compared the effects on achievement of both the autonomous and guided methods of instruction for discovery. Achievement was measured by two means: (1) Objective tests scores, and (2) the subject's ability to give the proper reasons for the correct responses on the objective tests. The analysis of these data produced ambiguous results. One set of test data indicated that the autonomous method was superior to the guided method. Two other sets of test data indicated that there were no significant differences in achievement under the two methods.

Criterion 2 -- Intellectual Potency and Cognitive Skills

No data were available for an evaluation by this criterion.

Criterion 3 -- Intrinsic Motivation

No data were available for an evaluation by this criterion.

Criterion 4 -- Transfer of Learning

A study by Craig compared all three basic methods of teaching for discovery. Since his study dealt with transfer, he evaluated the methods in terms of their effectiveness in promoting transfer. The subjects were 200 male college graduates. The learning task consisted of discovering the principles which determined how four of five words in an item are not related. The autonomous group was told only that one word did not belong with the other four. The items were presented to this group in random order. Although the guided group received the same instructions as the autonomous group, the order of the items presented to the guidedgroup was organized so that all items based on the same principle were presented together. The organization of the items presented to the directed groups was the same as that provided for the guided group. However, the directed group was informed that there were principles which determined the relationships among the words in each item, and that all items based on the same principle were grouped together. Transfer for the three groups was measured by a test utilizing similar problems. Of the three methods the directed method produced the best transfer. "The amount of transfer of training increases as more and more clues are provided to aid discovery of the bases for correct responses." (Craig, 1953). The results also indicated that the more difficult a task, the more significant are the effects of increased direction on aiding transfer.

Kersh (1958) made a study comparing the influence of the guided and directed methods on transfer. The results indicated that the guided method of instruction promoted better transfer of learning than the directed method.

Since the results of these two studies are conflicting, no conclusion can be made about the relative effectiveness of these methods.

Criterion 5--Heuristics of Discovery

No data were available for an evaluation by this criterion.

Criterion 6--Improvement of Memory Processes

The data found are relevant to retention only. The study by Kersh (1958) reported under Criterion 2 also compared the effects of the guided and directed methods of instruction on retention. He concluded that the guided method resulted in better retention than the directed method.

Criterion 7--Time and Steps Required for Discovery

In evaluating the effectiveness of two of the basic methods of teaching for discovery Sechrest and Wallace (1962) reported that the autonomous and guided methods were equally effective in producing discovery in terms of the number of steps required to reach the solution.

Bruner (1956) reports a study in which a comparison was made of the efficiency of the autonomous and guided methods of instruction. Subjects using the guided method consistently attained their discoveries faster and with fewer steps than the subjects using autonomous methods.

No conclusions about the relative effectiveness of the autonomous and guided methods can be reached because of the ambiguous nature of the data.

In summary, the data from these five sources have failed to establish, on the basis of the seven criteria used, the superiority of one method over the others. This conclusion stems from three facts: (1) the scarcity of data, (2) the nature of the data (few studies compared all three methods), and (3) conflicts or ambiguity within the data.

Summary

The effectiveness of methods of instruction for discovery have been evaluated. The evaluation was divided into two parts. The first part compared the effectiveness of methods of instruction for discovery and methods of instruction which do not utilize discovery. The limitations of the data did not permit specific types of methods of instruction for discovery to be compared to specific types of methods of instruction which did not utilize discovery. The comparison was made for the general methods of instruction for discovery and the general methods of instruction which do not utilize discovery.

The two diverse approaches to instruction were evaluated by six criteria derived from the advantages claimed for discovery learning. The six criteria are (1) the fostering of meaningful learning, (2) the strengthening and extension of intellectual potency and cognitive skills, (3) the extent of intrinsic motivation, (4) the promotion of transfer of learning, (5) the teaching of the heuristics of discovery, and (6) the improvement of memory processes. Data for the evaluation were gathered by a review of current literature on learning by discovery.

The results of the evaluation were largely inconclusive. No definite statement of the superiority or lack of superiority of the methods of instruction for discovery as compared to the methods of instruction which do not utilize discovery could be made for any of the six criteria. However there was some indication that methods of instruction for discovery may be slightly more effective than methods of instruction which do not utilize discovery in regard to intrinsic motivation and the promotion of memory processes.

The second part of the evaluation compared the effectiveness of three basic methods of instruction for discovery. The three basic methods, the autonomous, the guided, and the directed, were evaluated by the same six criteria used above. In addition a seventh criterion, the length of time and number of steps required for discovery, was used. Data for this evaluation were also gathered by a review of the literature on discovery learning.

The evaluation failed to establish the superiority of one method over the other two for any of the criteria used. The failure of the evaluation to find any method superior to the others in relation to a single criterion is belived to result from three limitations of the data: (1) the scarcity of data, (2) the nature of the data (few sources compared all three basic methods of instruction for discovery), and (3) conflicts or ambiguity within the data.

References

Ashton, Madeleine R. Heuristic methods in problem solving in ninth-grade algebra. Doctor's thesis. Stanford University, 1962.

Bruner, J. S., Goodnow, Jacqueline, and Austin, G. A. A study of thinking. New York: John Wiley and sons, 1956. Pp. 99-102.

Carpenter, F. The effects of different learning methods on concept formation. Science Education 1956, 40, 282-85.

Charen, G. A study of the effect of open-ended experiments in chemistry on the achievement of certain recognized objectives of science teaching. Paper presented at the Thirty-Sixth Annual Meeting of the National Association for Research in Science Teaching, Washington, D. C., February 20-23, 1963.

Craig, R. C. The transfer value of guided learning. New York: Bureau of Publications, Teachers College, Columbia University, 1953, p. 70.

Grote, C. N. A comparison of the relative effectiveness of Direct-Detailed and directed discovery methods of teaching selected principles of mechanics in the area of physics. Doctor's thesis, University of Illinois. 1960.

Haslerud, G. M. and Meyers, Shirley. The transfer value of given and individually derived principles. Journal of Educational Psychology 1958, 49, 297.

Hendrickson, G. and Schroeder, W. H. Transfer of training in learning to hit a submerged target. Journal of Educational Psychology 1941, 32, 305-13.

Hendrix, Gertrude. A new clue to transfer of training. Elementary School Journal 1947, 48, 198.

Huxtable, Zelma T. Learning outcomes following self-directed and formally guided responses in controlled situations. Journal of Experimental Education 1938, 6, 406-12.

Kersh, B. Y. The adequacy of 'meaning' as an explanation for the superiority of learning by independent discovery. Journal of Educational Psychology 1958, 49, 292.

Kersh, B. Y. The motivating effect of learning by directed discovery. Journal of Educational Psychology 1962, 53, 69-71.

Kittell, J. E. An experimental study of the effect of external direction during learning on transfer and retention of principles. Journal of Educational Psychology 1957, 48, 404.

Moss, J. Jr. An experimental study of the relative effectiveness of the direct-detailed and the directed discovery methods of teaching letterpress imposition. Doctor's thesis, University of Illinois, 1961.

Ray, W. E. Pupil discovery versus direct instruction. Journal of Experimental Education 1961, 29, 271-80.

Rowlett, J. D. An experimental comparison of direct-detailed and directed discovery methods of teaching orthographic projection principles and skills. Doctor's thesis. University of Illinois, 1960.

Sechrest, L. and Wallace, J. Assimilation and utilization of information in concept attainment under varying conditions of information presentation. Journal of Educational Psychology, 1962, 53, 157-64.

Stacey, C. L. The law of effect in the retained situation with meaningful material. Learning Theory in School Situations. University of Minnesota, Studies in Education, College of Education, No. 2. Minneapolis: University of Minnesota Press, 1949. Pp. 100-101.

Stokes, W. W. An analysis of learning by discovery. Florida Journal of Educational Research. 1966.

Suchman, J. R. The elementary school training program in scientific inquiry. Title VII Project Number 216, National Defense Education Act of 1958. Grant No. 7-11-038. University of Illinois, 1962. Pp. 79-129.