A Taxonomy of Problem-Solving Activities and Its Implications for Teaching

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A Rationale for a Taxonomy

"A Taxonomy of Problem-Solving Activities"--what is it and what use is it? The dictionary defines taxonomy as classification. In the world of biology and elsewhere, it has come to mean a classification for the purpose of study. We create a taxonomy to enable us to study the parts of a subject which is too large or too diffuse to be studied as a whole.

Problem-solving is just such a topic. Solving a problem is an activity which can consume days, months, or years, or can take place in a matter of seconds. It can subsume many behaviors or very few. It can be extremely complex or very simple. Consequently, it is almost impossible to talk or even to think about it as a whole. Discussion of problem-solving tends to degenerate to a discussion of one phase of problem-solving or even of solving a particular class of problems. Thus, general statements about problem-solving are often made which would be better addressed to a particular part of problem-solving.

The development and use of a taxonomy of problem-solving activities can help with these problems. By breaking problem-solving into its component activities it makes it possible to consider each activity separately without the mental haze which results from trying to think about too many related activities at one time. It enables the thinker to examine a problem-solving system for the presence or absence of appropriate activities and to take corrective measures. Last, it allows the thinker to describe more accurately the problem-solving process and thus communicate it to another.

Since a taxonomy is an aid to description and communication, it is of more use to the person who wishes to think about and talk about the problem-solving process than it is to the person who wishes to do problem-solving. thus it becomes a tool of utmost utility to the teacher who struggles to transmit the problem-solving process to the student rather than teaching the solution of specific problems.

A Problem-Solving Taxonomy (PST)

Most, if not all, problem-solving activities can be divided into five classifications: routines, diagnosis, strategy, interpretation, and generation.

There is no particular sequence for these classes of activity and in solving an actual problem the student will move back and forth among them according to the dictates of the particular problem. The following working definitions have been evolved for these activities:

Routines are those operations which, once begun, afford no opportunity for decision but proceed by simple or complex mathematical steps to a unique solution. Long division is a routine. The evaluation of a complex integral is a routine. The solution of a quadratic equation is a routine. The determination of the moment of inertia of a composite area about a centroidal axis is a routine. All of these depend only on the correct execution of a number of steps. The student may find it necessary to recall mathematical or physical facts in order to perform a routine but no decisions are necessary.

Diagnosis is the selection of the correct routine or routines for the solution of a particular problem. Diagnosis is sorting out correct routines from incorrect routines. Deciding on the flexure formula to find the stresses at a given point in a beam is diagnosis. Deciding on integration by parts for a given integration problem is diagnosis. In both cases there is only one way to go, but the student must find it. He must examine the problem until he finds a correct routine.

Strategy is the choice of a particular routine for the solution of. a problem which may be solved by several routines or variations of routines, all of which are known to the student. Strategy is choosing among correct routines. The selection of a point about which to take moments is a strategy decision. The decision to use polar rather than Cartesian coordinates is strategy. The use of the method of sections or of the method of joints in analyzing a truss is a matter of strategy.

Interpretation is the reduction of a real-world situation to data which can be used in a routine, and the expansion of a problem solution to determine its implications in the real world. It includes the making of appropriate assumptions and the interpretation of results.

Generation is the development of routines which are new to the problem-solver. It may simply be laying out a number of routines to put them together in new ways, in which case it is probably a matter of pure recall. It may be the bringing together of previously unrelated ideas to spark a new attack, in which case it is highly creative. It may be somewhere between these two extremes. It must result in an activity which is completely new to the problem-solver and which he has never been taught.

These are the five dimensions of problem-solving as the taxonomy defines them. A student enters with certain skill levels in each and exits with a different set of skill levels. The difference in these skill levels is a measure of what has been learned about solving problems. To teach problem-solving the teacher must address each of the five dimensions.

The present taxonomy does not deal with problem definition, because in most cases the engineer or the engineering student is set to solve a particular problem, large or small, rather than to discover the problem to be solved.

Other Learning Taxonomies

The reader of educational papers may wonder whether there is a need for a taxonomy of problem-solving. After all, excellent taxonomies of learning already exist. That is quite true. However, a closer reading will show that most of the existing taxonomies of learning behavior end where a taxonomy of problem solving begins.

The best known of all educational taxonomies is undoubtedly that of Bloom. His Taxonomy of Educational Objectives categorizes all cognitive behaviors as knowledge, comprehension, application, analysis, synthesis and evaluation. It is an extremely powerful tool, but its very rigor makes it difficult to use in teaching problem-solving. It is quite possible for two teachers to argue for hours over whether a given objective is actually comprehension or application, and to end up agreeing that it is really a bit of both. By focusing on groups of behaviors leading to a particular outcome, rather than on individual behaviors, the Problem-Solving Taxonomy cuts across Bloom's Taxonomy and groups behaviors as they occur in he solution of problems. For instance, diagnosis, an activity in the Problem-Solving Taxonomy, may combine knowledge, comprehension, and application as identified by Bloom.

In his eight type: of learning, Gagné lays out a hierarchy which culminates in problem-solving. Problem-Solving as Gagné sees it is 5 far narrower activity than that envisioned by the engineer. The Gagné problem-solving is quite analogous to the activity designated as "Routine" in the Problem-Solving Taxonomy. The Gagné hierarchy does not deal with the more complex activities involved in problem-solving.

In a later work, Gagné has delved somewhat deeper into problem-solving and has somewhat extended his range. An activity which he calls "rule learning" corresponds well with our "routines", and he has divided his problem-solving into four main areas: presentation of the problem, definition of the problem, formulation of hypotheses (both correct and incorrect), and verification. This approach looks at generation and analysis but ignores the areas of diagnosis and strategy.

In a very recent attempt to assemble and integrate various taxonomies, Holland and his co-workers have evolved a taxonomy with three main divisions: psychomotor learning, memory learning and complex cognitive learning. A subdivision of memory learning, algorithms, bears a considerable resemblance to routines. The remainder of the activities cataloged in PST are treated under "complex cognitive". There, under the heading of "principles", they consider an activity much like diagnosis, and their "strategies" grouping includes a mixture of strategy, generation, and application as identified in PSI.

The existing learning taxonomies are thus seen to be much more general and diffuse than PST, and require the teacher to utilize many different levels and even different taxonomies, in order to completely describe and analyze problem-solving activities as they are seen in the practice of engineering. It may be argued that the present Problem-Solving Taxonomy can be used to complement the more general learning taxonomies already in use, and can provide a useful specialized tool for the teacher whose primary concern is the teaching of problem solution. Other taxonomies are perhaps more useful in teaching the solution of one particular problem or class of problems. PST is most useful in teaching an approach to problem-solving in general.

Principal Approaches to Problem-Solving

It may be of some interest at this time to examine the approaches of several current schools of thought on problem-solving, and to describe them by means of the Problem-Solving Taxonomy (PST). For instance, brainstorming and synectics are aimed almost entirely at generation. Both are designed to facilitate the development of many alternative ideas for problem solution. The working out and evaluation of the ideas has no place in either system, but are saved for a later day.

On the other hand, Polya maps presume the generation to have already taken place and concentrate on the logical development of strategy based upon analysis. Process synthesis and computer simulations of human thought also emphasize strategy but base it upon some generation activity. The role of strategy in both approaches considerably outweighs the other activities.

Inquiry learning of all sorts is based upon meticulous questioning and thus can be characterized in PST-terms as primarily concerned with interpretation.

The cognitive and gestalt theories explain human behavior in terms of conscious, strategic purpose. "The organism perceives, thinks about, and analyzes its environment." In these theories, problem-solving is primarily seen as those activities which PST describes as diagnosis and strategy.

Behavioral psychology sees problem-solving, like all learning, as resulting from the reinforcement of correct solutions. It is not concerned with the mental mechanism by which problems are solved but with increasing the frequency with which problems are solved. In practice it becomes a powerful method for teaching routines and may produce some proficiency in diagnosis. It does not address generalized problem-solving skills.

There are many variations on these various schools of thought about learning in general and problem-solving in particular. These give varying degrees of emphasis to the activities described by the Problem-Solving Taxonomy. However, the PST appears to be equal to the task of describing any of them and may indeed provide a useful tool for comparing and contrasting the various approaches.

Types of Problems

The foregoing discussions should serve to help place the Problem-Solving Taxonomy in perspective with current theories about problem-solving. The remainder of this paper will be devoted to the use of PST in understanding and enhancing the development of the problem-solving activities of students. Before undertaking to use PST to classify the problem-solving activities of students, it is advisable to examine the sorts of problems they are expected to solve.

Problems can be classified as simple close-ended, complex close-ended, or open-ended. In all cases the problem solver combines ideas to produce an answer to a previously unanswered question. Often the combination of ideas is a new one for the individual problem solver, but this is not always so.

A simple closed-ended problem is one which has one right answer and one set, method by which that answer may be obtained. Taking the derivative of an algebraic expression is such a problem. In terms of the PST, simple closed-ended problems are solved primarily by diagnosis and routine.

A complex closed-ended problem is one which has one right answer but several methods by which the answer may be obtained. For example, many problems in dynamics may be solved by the use of Newton's laws, by energy methods, or by applying the principles of impulse and momentum, but the final answer will be the same no matter which method is chosen. The taxonomy would describe the solution of such problems as consisting of routines, diagnosis, and the use of considerable strategy.

Open-ended problems are those for which more than one correct solution can be found. However, an open-ended problem can be broken down into a cluster of close-ended problems. The correct solution is inherent once a method of attack is determined and appropriate assumptions are made. Different solutions are obtained by changing either the attack or the assumptions. Developing the attack is described in PST as generation, and choosing assumptions is interpretation. Thus, the open-ended problem emphasizes generation and interpretation at the same time that it requires all the routines, diagnosis and strategy used in close-ended problems.

The engineering curriculum attempts to develop in the engineering student the ability to solve all three types of problems. It meets with variable success. Often its successes and its failures seem to be more a matter of luck than good management. Nevertheless, engineering education does succeed. Engineering students do become problem solvers. The next section of the paper will be devoted to looking closely at how this occurs, describing the students progress by means of PST.

Problem-Solving and the Beginning Student

Generalization about students' skills in any area is a dangerous occupation. Nowhere is this more true than in the assessment of fresh-men. The effects of their varying backgrounds are still very strong. Nevertheless, most teachers will agree that a freshman is more like other freshmen than he is like a senior. It is this broad common pattern we shall examine.

What is the entrance profile of the freshman engineering student? There is tremendous variation in individuals and in institutions. There is quite probably a sex-related difference, although our observations of females have been too few to include. Nevertheless, let us examine the fictitious average entering male. What are his problem-solving skills?

He is essentially a specialist in routines. Most of his previous educational experience has been directed to teaching him more and more complicated routines. However, his most sophisticated experience with routines has been with multi-step single-path operations such as long division. He is not only good at routines; he is good at learning routines. He tries to reduce all of problem solving to the application of routines.

His skill in diagnosis is limited. He can select a formula such as the ideal gas law in order to initiate a routine, but his repertoire of such formulas is very small in any given area so that selection is relatively easy. He has had the most opportunity to develop diagnostic skills in mathematics, where he has had considerable practice in matching the method to the problem.

His skill in strategy is rudimentary. It is limited to choosing between orders of operation in a single routine. In other words, he can decide whether to take one arithmetic or algebraic step before another. The capability of his calculator has frequently taught him to make some strategy decisions in order to use it efficiently.

His skill in interpretation is almost non-existent. It consists almost entirely of the identification of knowns and unknowns in a problem statement so that he can use them in the routine he has selected. He is really at the stage of recognizing that a quantity given in units of psi is pressure and goes into the gas law as P, while a quantity given in cc is volume and goes in as V. He probably also knows that something will have to be done about the units. He has had no experience in making initial assumptions or in evaluating results.

His skill in generation is yet unborn. He will brand as unfair any problem which is dissimilar to those he has been taught to do.

Problem-Solving at the Midpoint

At the end of the sophomore year the student is halfway to his bachelor's degree insofar as course work is concerned. He is ready to leave the generalized instruction of the underclassman and enter upper-class specialization. What are his problem-solving skills at this point?

To describe the students' problem-solving skills at the end of two years of instruction we must once more generalize. Obviously some students will have made far greater strides than others. Sex-based differences will probably have diminished. However, the average student will have made some progress in all areas although he has not advanced equally in all.

He has added a great many routines to his repertoire and has learned to handle more complex kinds of routines. He is able to handle chaining routines where he must complete one routine to get to the beginning of a second, and must complete the second to begin the third, and so on until he reaches the final answer. He has also learned to work with interlocking routines where one routine must be completed and the result stored while second and third routines are completed and stored in their turn, until the results of all can be used together in a final routine. He has, in fact, advanced to the final stage of proficiency in using routines. Although he will probably learn additional routines through-out his professional life, he is unlikely to encounter any new patterns for routine calculation.

In the area of diagnosis the student has made comparable progress. He can now select a set of routines and order them so that the solution of one provides the starting point for the next or, in the case of an interlocking routine, break it down into the necessary subroutines. He has learned to incorporate feedback into the diagnosis. That is, at the end of one routine he can use its results to choose the next appropriate routine. He can also carry out parallel routines and, as a final step, compare their results and select the correct answer. In the area of diagnosis, as in routine, he has gone about as far as he can go. He will continue to practice his diagnostic skills and will become more proficient, but he has acquired the complete groundwork.

In the areas of strategy the battle has just begun. Coming in with essentially no skill in problem-solving strategy, he has learned a little but he still has a long way to go. He has learned to accept the existence of more than one acceptable approach to a problem. He can select an approach from several possibilities and is beginning to develop a rational basis for some selections. He can select a starting point for his work and he can evaluate the efficiency of alternative orders of operation in complex routines. None of these skills is really well developed. but he can handle strategies for ordering work within a routine better than he can handle strategies for selecting routines.

Students enter the sophomore year with very little skill in interpretation. They leave it with little more. They are able to translate more complex problem statements and drawings into usable data. They have been exposed to some information on the applicability of the material they are learning, but they have not yet practiced interpretation. That is probably as it should be, since interpretation must deal primarily with open-ended problems while the sophomore problem is almost entirely closed-ended.

In the area of generation a start has been made. The student has become accustomed to the idea of working "new" problems, using routines in situations where he has not been specifically taught to use them, or putting routines together in a way which he has never seen before. Mechanics courses generally have provided such practice and have forced the student to a realization that he will be repeatedly forced to solve such problems, unfair as he may view them.

Problem-Solving and the Upper Classman

During the first two years the student has become expert in routines and diagnosis and has taken the first steps in strategy, interpretation, and generation. During his final two years he will develop his abilities in the last three areas. The precise emphasis shifts from curriculum to curriculum, but all curricula develop these skills.

The junior year focuses primarily on the development of strategy. There is an emphasis on seeking the best way to solve a given problem. Routines and diagnosis are still taught but only in the sense of increasing the students' repertoire. Interpretation begins to be of considerable importance, as the students' attention is focused more and more on the real-world implications of his work. The ability to generate solutions continues to develop, as again and again the student is forced to face unfamiliar problems.

During the senior year all the processes already in motion continue. Routines, diagnosis, and strategy continue to be practiced with new material and new situations. It is in the design courses that application and generation become the primary focus of the teaching effort as the teacher tries to show the student how to bring all his previous work to bear on truly open-ended problems.

Implications for Teaching
This is the developmental pattern for problem-solving skills in engineering students as it can be observed in most engineering schools. Is it inevitable? Can it be changed by changing teaching techniques? Can the more complex skills be introduced earlier?

It would appear that this can indeed be accomplished by a teacher who becomes aware of what he is teaching in terms of generalized skills rather than of particular subject matter.

For example, most teachers are quite competent at providing practice by means of assigned homework problems. Homework problems focus primarily on learning and using routines and this may be the reason that students seem to be so much more proficient in this area of problem-solving than in any other. The typical homework problem requires a very simple interpretation step as the student reads the problem, a simple diagnosis that leads to the selection of a routine, and two pages of routine calculation. Thus students become far more expert in routine calculations than in interpretation or diagnosis. Obviously they learn best what they practice most.

How can the teacher increase the students' practice in the other areas of problem-solving? By devising activities, possibly homework, where the focus is on the non-routine areas. For instance, rather than asking that a problem be solved for an answer, the same problem could be posed and the student asked to:

1. Tell how he would solve it
2. Why he chose that method
3. The order in which he would perform the routines in the solution.

Fluency in strategy might be increased by posing a problem and asking the student to describe several possible plans of attack with the advantages and disadvantages of each, and to decide which he would choose and why. Attention should be paid to making the student conscious of the decisions he makes and the reasons for them.

If the emphasis of the lesson is on these questions rather than on working out the details, more problems can be posed and examined in a given period of time and the students' attention is directed to the importance of this part of problem-solving.

Thus, it would appear that by carefully examining the particular problem-solving activities involved in an instructional episode, instruction can be fine-tuned to develop a particular problem-solving skill. The last sections of this chapter will be devoted to suggesting some ways of developing each of the skills in the taxonomy.

Teaching Routines

There are obviously many ways to teach routines since such a large proportion of teaching effort is devoted to teaching routines. Some activities and media which seem particularly appropriate are listed in Table I. The list is by no means exhaustive, but includes those items the authors have found to be effective.

Table I		
Suggestions for Teaching Routines		
Teaching Techniques	Student Activities	Media
Identify routines as such Teach formalized routines	Homework Practice problems	Texts Programmed instruction
Put routine problems on tests Use "mastery" approach	Chalkboard work	Audiovisuals

The student activities and media columns are probably self explanatory, but some amplification may be in order for the items listed as teaching techniques.

The identification of routines is an important first step. The teacher should make sure in his own mind that the item to be taught is a routine and then teach it as such. He should not glorify the use of a simple equation into some higher-sounding teaching objective. Instead, he should show the students the proper use of the routine as a tool and tell them that he expects them to learn to use it accurately and quickly rather than worrying about the more intellectual issues he might raise.

Teaching routines in a formalized fashion is a direct outgrowth of the first technique. The teacher should help the student develop rules and formalized methods wherever possible. A good example of such formalization is the development of a tabular solution for finding moments of inertia of a composite body. If the table is properly laid out the solution becomes extremely easy.

By always devoting a portion of every test to routine problems, the teacher impresses the student with the value and necessity of routines and rewards the student for learning them. "Mastery" techniques are particularly useful here since it is easy to grade a routine on a pass or restudy basis, and thus to insist that important routines be performed at a very high level of accuracy.

<u>Teaching Diagnosis</u>

Table II shows a number of suggestions for enhancing the teaching of diagnosis. Most of the suggestions may be summarized as making sure that the teacher teaches diagnosis rather than merely expecting the student to learn T17--This seems to consist of calling the students' attention to the diagnostic process and making sure that the student has an adequate opportunity to practice it under some supervision.

Table II

Suggestions for Teaching Diagnosis

Teaching Techniques	Student Activities	Media
Teach criteria for diagnosis	Practice problems which emphasize choosing the correct method	Texts
Prompt student toward correct choice in early diagnosis problems		Programmed instruction
Include review problems throughout course without identification as review	Practice problems which emphasize recognizing diagnostic criteria	Audiovisuals
Cover several topics on each hour examination		

The authors have found it useful to make use of rather heavy prompting when the student first begins to learn the diagnosis process. This has the effect of making fairly sure that his initial diagnoses are correct, so that the student develops confidence in his own diagnostic ability and is not afraid of the process.

A student's repertoire of routines is rather small in the beginning stages. It is usually pretty well restricted to what he has learned in the particular course. The insertion of frequent unmarked review problems forces the students to sort repeatedly through his bag of tricks to find the one applicable to the problem in hand. Inclusion of several topics on each exam forces the same sort of sorting and rewards success in it. As the students' repertoire fills with material from other courses, it becomes less necessary to consciously provide opportunities for sorting. They become inherent in the problems posed.

Teaching Strategy

Table III shows a number of means of enhancing skills in strategy. Again the emphasis is on conscious instruction by the teacher on ways to select strategies, and adequate practice by the student in making strategy decisions. It is important that the teacher realize he is teaching strategy and that the student realize he is learning it.

The teacher who teaches strategy must make sure that the student has valid alternatives among which to choose. This means teaching several routines to achieve the same result, as well as teaching the student to follow parallel routines to different results among which results the student must finally choose. A classic example of the latter is the friction problem which determines whether a given object will tip or slip under loading.

Table III

Suggestions for Teaching Strategy

Teaching Techniques	Student Activities	Media
Teach multiple routines for same result	Practice problems involving strategy decisions	Texts
Teach parallel routines to alternative solutions	Lay out steps in a solution	Programmed instruction
Develop standards of comparison	Verbalize reasons for choice	Case Studies
Describe relative merits of routines	Polya maps	Design problems
Explain why teacher chooses a particular routine		

Probably the best way to teach strategy decisions is for the teacher to explain the mental steps that lead to the choice of a given strategy. The teacher should act out or model the thought process that leads to a decision, or actually think aloud before the class as he or she solves a new problem.

Similarly, the student activities which seem to be most useful are those which make the student lay out his thinking in some form or another. The student seems to learn best if he is required to do his thinking aloud or on paper, since this forces his attention to logical development rather than intuitive leaps, and makes him conscious of the thought process as well as the end result.

Teaching Interpretation

Table IV gives suggestions for strengthening interpretive skills. They are aimed primarily at giving the student a wealth of data to interpret and at presenting the data in as many forms as possible. It is somewhat easier to provide occasions for the interpretation of data leading to the beginning of a routine than to provide occasions for interpreting the outcome of the routine in real-world terms, but attention should be devoted to both aspects.

Table IV

Suggestions for Teaching Interpretation

Teaching Techniques	Student Activities	Media
Provide problems with excess information	Building models	Audio-tutorials
Give data in many forms, (verbal, drawings, etc.)	Building prototypes	Special notes
Give some data in "real" form (complete tables, graph, etc.)	Collection of field data	Lab manuals
Work with actual objects	Collection of library data	Handbooks
Model teacher's own interpretive process	Laboratories	Case studies
	Projects	
	Design problems	

Once again the teacher has an important role as he models the interpretation of data. He is particularly helpful in the beginning as he shows students how to convert observations into the basic data for a routine.

Teaching Generation

Table V suggests a very few ideas for teaching generation. Generation is particularly difficult to teach because very few people under-stand the means which they use to generate new ideas. Apparently the best plan is to provide opportunities for the students to attempt generation together with encouragement. About the only elementary activity in generation which the authors have been able to devise is the sort which asks a student to derive in polar coordinate an expression he knows in cartesian coordinates.

Table V

Suggestions for Teaching Generation

Teaching Techniques	Student Activities	Media
Give practice problems requiring novel use of a familiar routine	Devising a new path to a known result	Current literature
		Special notes
Give practice problems involving new combinations of routines	Design problems	Case studies
	Brainstorming	
Model teacher's own way of attacking new problem		

Until the teacher learns to produce new ideas on demand, he is in a poor situation to teach others to do so. However, modeling his own difficulties and their solution may be of some benefit to his students.

Summary

This paper has presented a simple and potentially-useful taxonomy of problem-solving activities. By its use it is possible to break problem-solving into its separate hierarchical but non-sequential activities, so that the attention can be focused on a specific skill. The paper has discussed the place of the taxonomy among similar taxonomies, and has used it to look at several schools of thought on problem-solving.

The taxonomy has also been used to describe a student's progress as he learns problem-solving skills, and has suggested methods for expediting that progress.

The taxonomy results in a simple and pragmatic approach to teaching problem-solving and for that reason is is believed that it may prove useful to others. It is presented not as a solution, but as a starting point upon which others may successfully elaborate.

References

1. Bloom, B. S., ***Taxonomy of Educational Objectives*** - Handbook I: Cognitive Domain, David McKay Company, Inc., NY (1956).

2. Gagné, R. M., ***The Conditions of Learning***, Holt, Rinehart, and Winston, NY (1965).
3. Gagné, R. M., ***The Conditions of Learning***, 2nd edition, Holt, Rine-hart, and Winston, NY (1970).
4. Holland, J. G., Solomon, C., Doran, J., and Frezza, D. A., ***The Analysis of Behavior in Planning Instruction***, Addison-Wesley, Reading, MA (1976).
5. Polya, G., ***Mathematical Discovery: On Understanding, . Learning and Teaching Problem Solving, Vol. I and II***, Wiley, NY (1961, 1965).
6. Rudd, D. F., Powers, G. J., and Sirola, J. J., ***Process Synthesis***, Prentice-Hall, Englewood Cliffs, NY (1973).
7. Newell, A. and Simon, H., "Computer Simulation of Human Thinking", ***Science*** 134, 2011 (1961).
8. Shulman, L. S., "Seeking Styles and Individual Differences in Patterns of Inquiry", ***School Review***, 73, 258 (1965).
9. Maier, N. R., ***Problem-Solving and Creativity: In Individuals and Groups***, Brooks/Cole, Belmont, CA (1970).
10. Skinner, B. F., "An Operant Analysis of Problem-Solving", in ***Problem-Solving: Research, Method and Theory***, Wiley, NY, p. 225 (1966)
11. Davis, G. A., ***Psychology of Problem Solving, Theory and Practice***, Basic Books, NY (1973).