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Critical Review of Problem Solving Processes Traditional Theoretical Models

Revisión crítica de los modelos teóricos tradicionales sobre solución de problemas

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ABSTRACT

This paper presents a brief analysis of most known problem solving theoretical models realized using epistemological categories such as observer position, object of study, methods and procedures, and descriptive or explicative scope. The review showed linear and cyclical models, the need to recognize method´s limitations to generalizing, the relevance of expliciting observer position, and a diffuse delimitation of the object "problem solving" as a cognitive process. An integrative and molar theoretical model of problem solving as a dependent variable is proposed whose variations go with critical cognitive processes (information processing, comprehension, reasoning, cognitive styles, and attitudes). Its molar feature refers to that it integrates basic and high order processes in a general cognitive activity; this proposal has to be extensively tested.

Key words: Problem solving, theory, cognitive, processes.

RESUMEN

Este escrito presenta un breve análisis de los modelos teóricos más conocidos de solución de problemas, realizado con categorías epistemológicas como posición del observador, objeto de estudio, métodos y procedimientos, alcance descriptivo o explicativo. La revisión mostró modelos cíclicos y lineales, la necesidad de reconocer las limitaciones para generalizar, la relevancia de explicitar la posición del observador y una delimitación difusa del objeto de estudio solución de problemas como proceso cognoscitivo. Se propone un modelo teórico de solución de problemas integrador y molar como variable dependiente cuyas variaciones dependen de procesos cognoscitivos críticos (procesamiento de información, comprensión, razonamiento, estilos cognitivos y actitudes). El carácter molar se refiere a que integra procesos básicos y superiores en una actividad cognitiva general; esta propuesta debe evaluarse extensivamente.

Palabras clave: Teorías, solución de problemas, cognoscitivo, procesos.

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SOME CLASSIFICATIONS OF CURRENT THEORETICAL MODELS

Tracing the evolution of the theoretical models of problem solving, we found that those that have shown the most transcendence in various domains of knowledge, as well as in different research processes, and that have achieved more academic diffusion, are the theories formulated by J. Dewey (1910/2007), Durkin (1937, cited by Guilford, 1986), Osborne (1963), Polya (1957/2007), Wertheimer (1959), Newell and Simon (1972), Donald Broadbent (1977), Hayes (1978), Hayes & Simon (1985), Greeno (1978, 1980), Sternberg (1986), Davidson and Sternberg (2003), Dietrich Dörner (1975, 1985), Bransford & Stein (1983, 1987), Simonton (1984), Vosniadou and Ortony (1989), Whimbey and Lockhead (1991), Kahneman and Tversky (1973), and Poissant, Poellhuber and Falardeau (1994).

Some authors have made efforts to identify common elements between the models and the concepts, and they have proposed bimodal or bipolar classifications; for example, Roth and McGuinn (1997) identified both linear models that describe problem solving as a relatively unvarying sequence of steps, and cyclic models according to which end of one problem is the beginning of another. Funke and Frensch (1995) arrange the theoretical developments considering the tradition to which they belong, thus, the NorthAmerican models have a functional base, and the European theories correspond to a structuralist tendency. In a previous article we proposed (Botia & Orozco, 2005) using the molar and molecular categories, taken from chemistry to psychology by E. Tolman (1948) and B.F. Skinner (1957), to classify the models; we argued that if a model is oriented to global analysis it can be considered a molar model, but if a model identifies processes, operations or components that take part in problem solving in a sequential or integrated manner, it can be considered a molecular model.

These analyses coincide in some points: (a) they criticize the limitations of the models because most of them are formulated from a starting point of research that uses structured tasks, related to known knowledge domains, and do not explain problem solving in everyday life, or complex problem solving; (b) they state that most of the proposals assumed that the mental operations to use or to develop are the same to deal with any kind of problem; (c) they point out that the available theories of the problem solving process stay at a descriptive level; (d) they censure that a unified theory of problem solving does not exist, nor has it been developed, such that it may be the basis of other studies, and help in the design of generalizable tests, and that it may be able to answer the hard criticisms that emerge and come from other disciplines because cognitive psychology does not have comprehensive theories of cognitive phenomena (Zayour, 2002).

EPISTEMOLOGICAL VIEW

The analysis of the theoretical models of problem solving using epistemological categories such as object delimitation, method of research, method of theoretical construction, becomes an epistemological criticism, or at least, an epistemological analysis of the object delimitation and of how rigorous the methods of inquiry and theoretical construction are. In this perspective, the main questions were: (i) which is the observer perspective in these models? And (ii) whether the models study the same object or whether they refer to different aspects of the problem solving process, or other cognitive elements or processes? These analyses permit us to state that: a) the theoretical models with descriptive or explicative scope (Hayes, 1978; Greeno, 1978; Davidson & Sternberg, 2003) are mixed with theoretical models characterized by having as a main purpose to prescribe how the solver must proceed when he faces a problem (Osborne, 1963; Polya, 1957/2007; Newell & Simon, 1972), although none of the authors talk about the scope issue; (b) most of the theoretical models of problem solving have been formulated from the point of view of an external observer, and, from there, they identify the steps that a solver must go through (Polya, 1957/2007; Osborne, 1963; Newell, & Simon, 1972) to solve the problem. More recent models try to inquire into problem solving from an "internal" point of view of the observer, looking for the cognitive processes that take part in the task of solving a problem (Greeno, 1978; Simonton, 1984; Poissant et al., 1994). It seems very difficult for the external position models to sufficiently explain phenomena like insight, but likewise, the "internal" theories have difficulties identifying and bringing into relation the more relevant cognitive processes to explain the same insight and other frequent facts of cognition evident in problem solving.

For the second question, it was found that most of the theories prioritize and answer the question How are problems solved?, instead of attending to the question What is problem solving, or how can it be conceived?. Dewey (cited by Castillo, 2002) proposed understanding problem solving as a structure conformed by 5 phases: perceived difficulty, understanding and definition of the problem, list of possible solutions, hypothesis, test of applied solutions. Landau (1987) found a reduction of the Dewey proposal made by Johnson (1955) into three phases: preparation, production, judgment; Polya (1957/2007), who is considered an important communicator of Dewey's ideas (Wilson, Fernandez, & Hadaway, 1993), stated as steps to problem solving: to formulate objectives, to define the situation, to plan, to generate ideas, to choose an alternative of solution, to execute the chosen alternative, and to test the results. Sternberg (1986) and Davidson and Sternberg (2003) have described problem solving as a cycle, that does not function necessarily as an unvarying sequence, that includes the following steps: to recognize or to identify the problem, to define and to mentally represent the problem, to develop a solving strategy, to organize the solver's knowledge about the problem, to allocate the mental and physical resources to solve it, to check the progress towards the goals, and to test the adjustment of the solution to the particular situation. Poissant et al. (1994) included metacognition as a control and feedback instance, from whence the efficiency of the problem solving steps and results are ordered and tested.

Newell and Simon (1972) developed the GPS Model (General Problem Solver) which has been transcendental in theoretical and methodological research advances of the different traditions of problem solving theories for the last 30 years. These authors stated that behavior is a function of memory operations, and of the control rules and processes, in such a way that problem solving could be modeled by a machine because both the computer and the human mind are kinds of "information-processing systems". The GPS model tries to define the core processes that a solver can use to face different kinds of problems, and it is based on the assumption that a system of physical symbols has enough resources to attend to the environmental demands and to display intelligent behavior. The critical step when a problem is solved, according to this model, is the definition of the problem's space, this means to define the goal to be obtained, and of the rules of transformation. When the solver uses an end-means analysis, he divides the final goal into subgoals and tries to reach them. Some of the logical rules include: (1) to transform an object into another; (2) to reduce the difference between two objects; (3) to apply an operator to an object.

From a different point of view, Wertheimer (1959) proposed to consider a problem as a whole, so that in this way, the restructuring of situations and the reorganization of perceptions can propitiate insight, which means to see the problem from a different perspective: in this way the subject makes groups, reorganizes, and gives another structure to the information, keeping in mind and managing it to arrange as a whole the different elements that are present in a problem. This gestalt model assumes that a problem is an open figure able to excite, and cause tension such that the solver finds himself moved to restore equilibrium by getting a closed figure. In his own way, Durkin (1937, cited by Guilford, 1986) considered three ways to face a problem: trial and error, sudden reorganization, and progressive analysis, putting emphasis on the processes that a solver must do to reorganize the inconclusive information, keeping in mind not to assume sequences or steps to be followed by the solver. Dörner (1975, 1985; Dörner & Wearing, 1995) emphasized the interplay between the motivational and social components as relevant variables to understand problem solving, and Broadbent (1977) distinguished processes involved in problem solving that are present to awareness, and some others that can not be perceived, that work outside of awareness. From a perspective of elements combination, Simonton (1984) argues that the basic units of the creative process, named mental elements, must be freely combined in different combinatory possibilities, so that the permutation probabilities of an element is the central point of creative problem solving.

Greeno's studies (1978) showed the relevance of general or specific knowledge about a particular domain in problem solving; he points out the necessity of establishing, clearly, when a solver operates efficiently because he takes into account the appropriate knowledge, or because he has good competencies to solve the problem. The cited author identified three kinds of problems: problems of organization, problems of induction, and transformational problems, and for each type he identified a different problem solving strategy. Vosniadu and Ortony (1989) and Vosniadu (1989) describe problem solving as a set of operations that are activated to transfer the principles of a successful past or known solution to a new problem; they explain that the more the knowledge domains differ from each other, probably the more creative will be the results. Whimbey and Lockhead (1991) outline the convenience and necessity of developing dimensional models for each problem; in these kinds of models a concept has a relative position in a space limited by the dimensions, and this position makes it possible to start from the essential premises to get the answers (solutions) by means of analogies.

This review shows that there are different approaches and ways to understand problem solving, and also shows that these theories have not asked, at least in a consistent manner, what is problem solving, how is it "configured"? As has been seen, most of them have proposed sequences of cognitive operations that are assumed to be relatively invariant and universal; others, a smaller number, try to isolate and emphasize one or another process particularly relevant to problem solving. So, it is necessary to recognize that the models we have studied have not lead to a theory that identifies, describes and explains the relevant cognitive processes that take part in the problem solving situations where a solver, novice or expert, faces diverse or complex problems and solves them, either in a predictable, or else an innovative or optimum, way. Problem solving research still has a way to go, and must be precise about the solver processes, the interaction between his qualities and the problem's characteristics, and the probable vicissitudes that can emerge when a solver faces unexpected, very complex, unstructured or unpredictable problems (Jonassen, 1997; Roth & McGuinn, 1997).

It is especially important to analyze problem solving models from an epistemological perspective in order to advance and clarify issues such as replication and procedure consistency in such a way that it could be possible to evaluate the strength of the methods used to reach hypotheses and conclusions incorporated in theoretical formulations. As a first exercise in this analysis, some publications and references of the cited authors were studied, and we reached some interesting findings.

From the reviewed literature it is possible to infer that the arguments of J. Dewey (1910/2007), in general, were based on the analysis of rigorous observations and on philosophical reflections; brainstorming was a discovery or an insight of Alex Osborne dated from 1939 when he became, an advertising executive; G. Polya, a renowned mathematician worried about math education according to Wilson et al. (1993), put into contrast Dewey's and his own observations in his educational activity, and based on this, formulated a description of the problem solving process; based on logic, systems theory, and recent developments in information processing, Newell & Simon (1972) with the help of deductive processes, achieved the construction of the General Problem Solver (GPS) model; this theoretical model was tested through the development of a computer simulation, and subsequently, they compared the machine results with human results in various tasks using protocols of analysis where the verbal report of the subjects was registered as containing indicators of the cognitive processes.

From then on, authors such as Donald Broadbent (1977), Hayes (1978), Greeno (1978), Simonton (1975), Vosniadou and Ortony (1989), Whimbey and Lockhead (1991), Kahneman and Tversky (1973), Poissant et al. (1994) have an empirical and experimental research background, that facilitates the replication of their studies, and as an important consequence, they obtain a stronger theoretical consistency for their conclusions from a positivist point of view. R. Sternberg (1980) and Davidson and Sternberg (2003) deserve special attention because of their continued work on problem solving and intelligence research for more than 20 years.

This brief revision shows two groups of theories: descriptive theories and explicative theories (we do not include prescriptive theories, those that pretend to establish how the solver must proceed when faced with a problem); the descriptive and explicative theories, analyzed with methodological criteria, showed stages that began with naturalistic observation, case studies, design of psychometric tests, algorithmic or heuristic task design and analysis, but recently use computer modeling or simulation, and activities maps. It is possible to affirm that the first stages lent fragility to early theories because their conclusions were imbued with philosophical assumptions that were difficult to be contrasted (Dewey, cited by Castillo, 2002; Polya, 1957/2007 models) and, in a similar way it is possible to say that some of their principles may have become beliefs or mythical statements like the Osborne model (Roth & McGuinn, 1997); these statements imply that their studies have difficulties in being replicated and allow sources of fragility in their authors' formulations. In spite of this characteristic, these early theories have supported and enhanced experimental and computational studies of problem solving. In this context, the development and qualification of the research instruments (techniques, tests, tasks) is a principal issue, considering that everyday problems are much more complex and frequently unstructured and unpredictable, with a greater number of variables that do not necessarily imply one unique correct solution. This is a great issue to work on, and the results will be presented elsewhere.

A task remaining for investigators is to establish if the methodological differences make the theoretical differences greater, or not, and how-why selecting one or another methodological approach could or could not help to arrive at more comprehensive theories. It seems that cognitive processes are interrelated with those individual differences that proceed from genetic, learning and cultural variables, and these relations influence the logic of problem solving. This overview proposes a research challenge, considering an adaptive perspective that gives priority to the successes or failures that result when a person solves in any way a situational need or obstacle.

In spite of the multiplicity of theories, methods and measurement tests developed in problem solving research in cognition, a better theory is still necessary, more integrative, with a stronger explicative capacity about problem solving (Funke & Frensch, 1995), especially when it takes into account complex problems (Davidson & Sternberg, 2003). The need for principles, laws, models with empirical evidence, demands a rigorous evaluation of current theoretical models, a test of their descriptive and explicative capability, a test of their generality. Until now, the literature does not show studies oriented towards this purpose.

TOWARDS AN INTEGRATIVE MODEL OF PROBLEM SOLVING PROCESSES

It is possible to generate and to test a theoretical model of problem solving starting with the identification of its critical or more relevant components, those processes that must be present in order to solve any problem, those that without their presence it becomes so difficult to solve a problem. Here, we propose that it is possible to understand problem solving as a general cognitive activity that has the principal role of integrating effectively basic and higher order cognitive processes, among which are especially important the processes of information processing, comprehension, reasoning (inductive and deductive), analogical transfer, cognitive styles, and attitudes to problem solving. These six processes have been selected because the literature has identified them as useful predictors of problem solving success in different kinds of tasks (Jonassen, 1997; Poissant et al., 1994). The problem solving process is a very complex activity that has a predictable margin of error (Kahneman & Tversky, 1973), unavoidable in most everyday situations.

From this perspective, problem solving can be understood as a dependent variable that has magnitudes and indicators that are a function of the above mentioned processes (information processing, comprehension,, etc); so, the performance level in each component is put together with other results, forming a profile of each subject, and so, it is possible to find a problem solving pattern. This way of measurement can be used as a predictor of the subject's performance in tasks and activities where problem solving is critical to success.

This formulation must be tested with empirical procedures that must take into account that it is constructed to be a molar proposition, because of its purpose of embracing the different components of cognitive phenomena, and of relating them, systematically and wholistically, to produce an integrative and synthetic view of problem solving. To assume a molar position for such theory does not deny the necessity, and the obligation to pass on to the molecular analysis of the components: their functioning, their structure, and their relations. This model has begun to be tested: a battery was designed (BSP04) that measures the six processes considered as most relevant, and this test permits us to obtain a profile that statistically can organize groups including the combined effect of the independent variables in the problem solving profile.

This proposal recognizes itself as a partial view of a very complex object of study, that at least includes three independent but related entities: the solver, the problem (or the task) and the relation between them; the analysis of this map of these three objects produces a great number of possibilities and combinations in any reader's perspective.

We recognize that to do research on problem solving as a cognitive process in such a perspective is a difficult challenge because facing simple or complex problems in everyday life - most of the time- does not have unique solutions; most likely, there are just good and better solutions, ones that are more effective and strategic than others; rarely a person finds one, unique and best solution in everyday life. This point of view is especially relevant when political and technical decisions related to social development are analyzed and considered as problem solving processes.

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